Chapter 2: South Florida Hydrology and Water Management

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SUMMARY

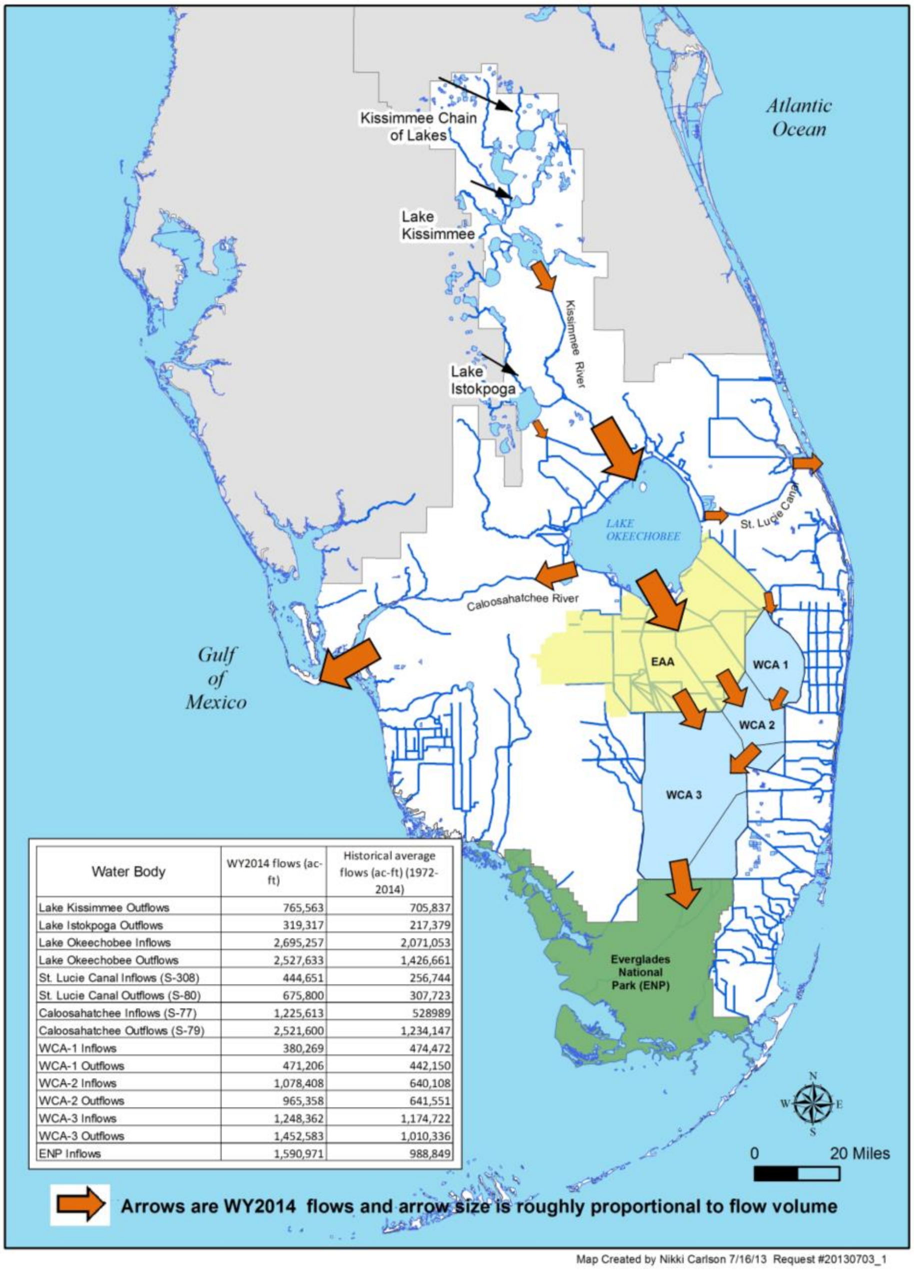
Given hydrology's significance to the entire South Florida ecosystem and all aspects of regional water management, this chapter presents hydrologic data and analysis for Water Year 2014 (WY2014) (May 1, 2013–April 30, 2014). Similar information from previous water years is available in Chapter 2 of the respective *South Florida Environmental Report* (SFER) – *Volume I.* This year's chapter includes a brief overview of the regional water management system, hydrologic impact of WY2014 tropical systems, a major rainfall event in January 2014 in the east coast, WY2014 hydrology of several sub-regions, and major hydrologic units within the South Florida Water Management District (SFWMD or District) boundaries. Appendices 2-1 through 2-6 of this volume provide supplementary information for this chapter. The broad influences of water year hydrology on various aspects of the region-wide system are covered in most other Volume I chapters. The El Niño-Southern Oscillation (ENSO) climatic phenomenon is linked to South Florida hydrology. The 2013 neutral condition continued in early 2014 but, by spring 2014, the tropical Pacific west of Peru started warming and the chance of El Niño increased.

Meteorologically, WY2014 was an above average rainfall year (+2.39 inches) with only two rainfall areas and the Everglades National Park (ENP or Park) experiencing below average rainfall year. Temporally, on the average, six months experienced drier than average rainfall. In most rainfall areas, August, September, and October of the wet season months were drier than average. However, June and July from the wet season and May and January from the dry season were wet enough to make up the deficit and drive the overall water year rainfall to above average. Spatially, Lower Kissimmee (+8.88 inches), Broward (+6.73 inches), Southwest Coast (+6.3 inches), Water Conservation Area 3A (+2.73 inches), Martin/St. Lucie (+2.66 inches), Miami-Dade (+2.42 inches), Lake Okeechobee (+1.97 inches), and Water Conservation Areas (WCAs) 1 and 2 (+1.96 inches) were wetter than normal. West Agricultural Area (-6.2 inches), ENP (-5.14 inches), and East Agricultural Area (-2.8 inches) experienced a drier than average rainfall year. WY2014 conditions represented a shift from previous water years, as WY2011 (-12.39 inches) and WY2012 (-3.65 inches) were drier than average and WY2013 was an average rainfall year.

Lake Okeechobee—the main storage of the regional water management system—was at a stage of 13.44 feet National Geodetic Vertical Datum of 1929 (ft NGVD) on May 1, 2013. The lake stage increased to 16.05 ft NGVD by August 10, 2013 due to wet May, June and July 2013 in the Upper Kissimmee, Lower Kissimmee and Lake and the rest of the lake watershed. The lake stage followed a gradual decline through the dry season reaching 13.07 ft NGVD by the end of WY2014. During this period, there was no concern of water supply.

Acknowledgments: The authors acknowledge Luis Cadavid and the District's Water Control Operations Bureau contribution in providing regular and temporary regulation schedules and Lake Okeechobee water management decisions.

Figure 2-1 presents WY2014 surface water flows for major hydrologic components in the regional system with historical average flows shown for comparison. **Table 2-1** compares WY2014 flows to the last water year's flows and historical average flows. Generally, inflows and outflows to most major water bodies were well above the historical average except inflows into WCA-1. WY2014 flows were higher than WY2013.



Water Body	WY2014 flows (ac-ft)	Historical average flows (ac-ft) (1972-2014)
Lake Kissimmee Outflows	765,563	705,837
Lake Istokpoga Outflows	319,317	217,379
Lake Okeechobee Inflows	2,695,257	2,071,053
Lake Okeechobee Outflows	2,527,633	1,426,661
St. Lucie Canal Inflows (S-308)	444,651	256,744
St. Lucie Canal Outflows (S-80)	675,800	307,723
Caloosahatchee Inflows (S-77)	1,225,613	528989
Caloosahatchee Outflows (S-79)	2,521,600	1,234,147
WCA-1 Inflows	380,269	474,472
WCA-1 Outflows	471,206	442,150
WCA-2 Inflows	1,078,408	640,108
WCA-2 Outflows	965,358	641,551
WCA-3 Inflows	1,248,362	1,174,722
WCA-3 Outflows	1,452,583	1,010,336
ENP Inflows	1,590,971	988,849

Figure 2-1. Water Year 2014 (WY2014) (May 1, 2013–April 30, 2014) and historical average inflow and outflow (in acre-feet, or ac-ft) into major hydrologic units of the regional water management system. [Note: The three arrows depicted from Lake Okeechobee represent lake outflows in inset; the inflow arrow into Everglades National Park (ENP or Park) includes outflow from Water Conservation Area 3 (WCA-3) and inflows from the east.]

Table 2-1. Summary of flows for WY2014, the percent of historical average they represent, and their comparison to WY2013. [Note: Structures used to calculate inflows and outflows into the major hydrological units are presented in Appendix 2-5 of this volume.]

Location	WY2014 total flow (ac-ft)	Percent of historical average	WY2013 total flow (ac-ft)
Northern Everglades			
Lake Kissimmee Outflows	765,563	108	439,653
Lake Istokpoga Outflows	319,317	147	280,544
Lake Okeechobee Inflows	2,695,257	130	2,100,036
Lake Okeechobee Outflows	2,527,633	177	1,041,902
Flows into St. Lucie Canal from Lake Okeechobee	444,651	173	103,622
Flows into St. Lucie Estuary through St. Lucie Canal	675,722	220	152,722
* Lake Okeechobee Releases to St. Lucie Estuary	418,559+		
* C-44 basin runoff into St. Lucie Estuary	257,154+		
Flows into Caloosahatchee Canal from Lake Okeechobee	1,225,613	232	501,374
Flows into Caloosahatchee Estuary through Caloosahatchee Canal	2,521,600	204	1,137,904
* Lake Okeechobee Releases to Caloosahatchee Estuary	1,146,488+		
* Basin runoff into Caloosahatchee Estuary	1,377,052+		
Southern Everglades			
Water Conservation Area 1 Inflows	380,269	80	363,897
Water Conservation Area 1 Outflows	471,206	107	483,713
Water Conservation Area 2 Inflows	1,078,408	168	1,074,320
Water Conservation Area 2 Outflows	965,358	150	938,199
Water Conservation Area 3 Inflows	1,248,362	106	1,322,042
Water Conservation Area 3 Outflows	1,452,583	144	1,225,088
Everglades National Park Inflows	1,590,971	161	1,496,719

* calculated estimates derived from Chapter 10 of this volume

INTRODUCTION

THE SOUTH FLORIDA WATER MANAGEMENT SYSTEM OVERVIEW: A REGIONAL OVERVIEW

The ecological and physical characteristics of South Florida have been shaped by years of hydrologic variation—ranging from extreme drought to flood, sometimes within a relatively short time period. The regional hydrology is driven by rainfall, rainfall-generated runoff, groundwater recharge and discharge, and evapotranspiration. Surface water runoff is the source for direct and indirect recharge of groundwater, lake and impoundment storage, and replenishments of wetlands. Excess surface water is discharged to the peninsula's coasts. Most of the municipal water supply is from groundwater that is sensitive to surface recharge through direct rainfall, runoff, or canal recharge. The general hydraulic gradient is north-to-south, where excess surface water flows from the Upper Kissimmee Basin in the north to the Everglades in the south, with water supply and coastal discharges to the east and west. The current hydraulic and hydrologic system includes lakes, impoundments, wetlands, canals, and water control structures managed under water management schedules and operational rules.

The development of South Florida requires a complex water management system to manage floods, droughts, and hurricane impacts. Excess water is stored in lakes, detention ponds, wetlands, impoundments, and aquifers, or is discharged to the coast to estuaries and the ocean. Information regarding the operation of the South Florida water management system is summarized in Abtew et al. (2011). As a major component of this system, Lake Okeechobee's storage capacity is over 3.54 million acre-feet (ac-ft) at average lake level of 14.02 feet National Geodetic Vertical Datum of 1929 (ft NGVD)—the largest of any hydrologic feature in South Florida. The lake is critical for flood control during wet seasons and water supply during dry seasons. Lake outflows are received by the Everglades Agricultural Area (EAA), St. Lucie River and Estuary, Caloosahatchee River and Estuary, and sometimes the Everglades Stormwater Treatment Areas (STAs). In drought conditions, some water is sent south for water supply. Further details of these sub-regional flows are presented in the *Water Levels and Flows* section of this chapter.

Over an 18,000-square-mile area, the District manages the region's water resources for flood control, water supply, water quality, and natural systems' needs under water management schedules based on specific criteria. The major hydrologic components are the Upper Kissimmee Chain of Lakes, Lake Istokpoga, Lake Okeechobee, EAA, Caloosahatchee and St. Lucie River basins, Upper East Coast (UEC), Lower East Coast (LEC), Water Conservation Areas (WCAs), Lower West Coast (LWC), and Everglades National Park (ENP or Park). The Kissimmee Chain of Lakes (Lake Myrtle, Alligator Lake, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) is a principal source of inflow to Lake Okeechobee. Various groundwater aquifers are part of the water resources, with most of their water levels responding relatively quickly to changes in rainfall and surface water conditions.

Generally, the region is wet with an average annual rainfall of 53 inches. For water management purposes, the District has divided the region into 14 rainfall areas plus the ENP (**Figure 2-2**). Rainfall for each area is reported daily, and multiple and overlapping gauges are used to compute average rainfall over each area. Real-time rainfall observations over the rainfall areas aid real-time water management decisions. Due to the relatively low gradient of regional topography, pumping is necessary to move water in the system. Across the region, the average pumping volume for Fiscal Years (October 1–September 30) 1996 through 2013 was 2.86 million ac-ft (**Table 2-2)**. Fiscal Year 2013 pumping was the highest volume, 4,419,510 ac-ft. In many cases, the same water is pumped in and out, as is the case with most of the Everglades STAs. The number of pump stations has increased from 20 to over 70 since 1996, with additional temporary pumps that vary in number from time to time. Some pumps are installed but not yet certified/registered and fully operational.

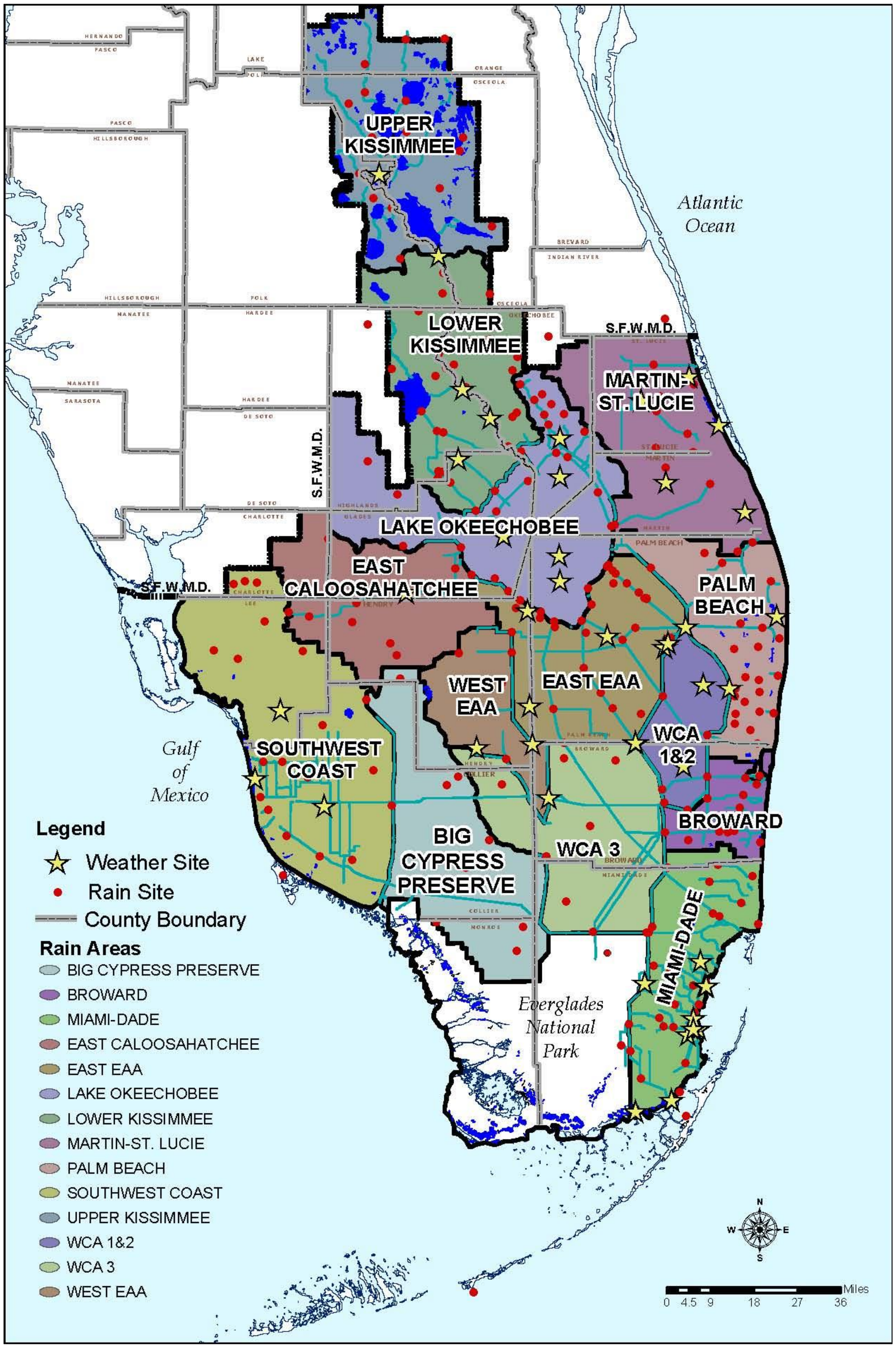


Figure 2-2. The South Florida Water Management District's (SFWMD or District) rainfall areas.

Table 2-2. District water pumping volumes for Fiscal Years 1996–2013 (October 1, 1995–September 30, 2013).

Fiscal Year	Volume of Water Pumped (ac-ft)
1996	2,480,000
1997	1,840,000
1998	2,020,000
1999	2,090,000
2000	2,517,000
2001	2,131,000
2002	3,131,000
2003	3,339,000
2004	3,404,000
2005	3,938,000
2006	3,583,000
2007	1,281,000
2008	3,767,700
2009	3,660,000
2010	3,031,622
2011	1,584,057
2012	3,254,308
2013	4,419,510
Average	2,859,511

STORAGE OF LAKES AND IMPOUNDMENTS

Storage is required for both flood control and water supply in the regional water management system. The amount of storage volume available varies significantly from year to year due to large variations in rainfall and runoff both temporally and spatially. The impact of variation in rainfall amount and timing is reduced by managing available storage. Regulation schedules provide guidance for water level/storage management of lakes and impoundments. The regulation schedule for each water body is covered in the following sections where WY2014 water levels are discussed. Temporary modifications from normal regulation schedules for WY2014 are also presented. Regulation schedule deviations include environmental needs, such as Everglade snail kite (*Rostrhamus sociabilis plumbeus*) needs and construction and maintenance activities.

The combined average storage of the major lakes and impoundments is over 5.2 million ac-ft; Lake Okeechobee provides about 68 percent of this storage volume. During wet conditions and high flow periods, storage between the actual stage and maximum regulatory stage is limited and water has to be released. The successful operation of the system depends on timely water management decisions and the constant movement of water. Excess water is mainly discharged to the Gulf of Mexico, St. Lucie Estuary, Atlantic Ocean, and Florida Bay. Stage-storage relationships of lakes and impoundments are critical information for managing water levels and storage and computing average hydraulic residence time. Appendix 2-2 in the *2007 South Florida*

Environmental Report (SFER) – *Volume I* (Abtew et al., 2007a) presents the compiled charts for stage-storage for the major lakes and impoundments and stage-area relationships where data are available.

SELECTED HYDROLOGIC COMPONENTS

During WY2014, most of the District regions received above average rainfall. Conceptual descriptions of these areas are summarized in this section, while specific hydrology and structure flow information for each is presented in the *Water Management in Water Year 2014* section of this chapter.

Upper and Lower Kissimmee Basins

The Upper Kissimmee Basin comprises the Kissimmee Chain of Lakes with a drainage area of 1,596 sq mi (Guardo, 1992). Historically, the Kissimmee Chain of Lakes is hydraulically connected to the Kissimmee River; during the wet season, the lakes overflow into surrounding marshes and then into the river (Williams et al., 2007). Water from the Upper Kissimmee Basin is discharged into the Lower Kissimmee Basin as the outflow of Lake Kissimmee. The Lower Kissimmee Basin has a drainage area of 727 sq mi (Abtew, 1992). Flows are through the restored segments of the Kissimmee River and C-38 Canal. Along the reaches of the river, there are four water control structures (S-65A, S-65C, S-65D, and S-65E) that regulate the river stage. Discharge from the S-65E structure flows into Lake Okeechobee as the main source of inflows to the lake. Overall, the Kissimmee Basin is an integrated system consisting of several lakes with interconnecting canals and flow control structures (see also Chapter 9 of this volume).

Lake Okeechobee

Lake Okeechobee is the largest lake in the southeastern United States. It is relatively shallow with an average depth of 8.9 ft and surface area of 436,300 acres at the average water surface elevation of 14.02 ft NGVD. Water levels are regulated through numerous water control structures operated according to a seasonally varying regulation schedule. The lake serves multiple functions for flood control, water supply, recreation, and environmental restoration efforts. Chapter 8 of this volume discusses the status of Lake Okeechobee.

Everglades Agricultural Area

The EAA is an agricultural irrigation and drainage basin where, generally, ground elevation is lower than the surrounding area. During excess rainfall, runoff has to be pumped out of the area; during dry times, irrigation water supply is needed. Irrigation water supply during dry seasons comes mainly from Lake Okeechobee, with the WCAs as secondary sources. On average, about 900,000 ac-ft of water is discharged from and through the EAA to the south and southeast, historically mostly discharging into the Everglades Protection Area (EPA) (Abtew and Khanal, 1994; Abtew and Obeysekera, 1996). Four primary canals (Hillsboro Canal, North New River Canal, Miami Canal, and West Palm Beach Canal) and three connecting canals (Bolles Canal, Cross Canal, and Ocean Canal) facilitate runoff removal and irrigation water supply. Currently, runoff/drainage from the EAA is discharged to the Everglades STAs for treatment and released to the EPA. Additional information on the EAA and STAs is presented in Chapters 4 and 5B of this volume, respectively.

Upper East Coast

The main canal in the UEC is the St. Lucie River (C-44 Canal). It runs from Lake Okeechobee to the St. Lucie Estuary. Inflows to the St. Lucie River are runoff from the basin and releases from Lake Okeechobee by operation of the S-308 structure according to regulation procedures described by the U.S. Army Corps of Engineers (USACE, 2008). Downstream of S-308 is a gated spillway, S-80, that also receives inflows from the local watershed to the west and discharges to the estuary. The C-23 canal discharges into the North Fork of the St. Lucie River at structure S-48. The C-24 canal discharges into the same fork at S-49. The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50.

Lower East Coast

The LEC includes urban areas in Palm Beach, Broward, and Miami-Dade counties. The purposes of the major canals in the LEC are flood control, prevention of over-drainage in the area, prevention of saltwater intrusion into groundwater, and conveyance of runoff to the ENP when available. The system is also intended to improve water supply and distribution to the ENP. It was designed to supply water during a 10-year drought and deliver minimum water needs to Taylor Slough and the C-2, C-4, C-1, C-102, C-103, and C-113 basins. The stages in canals are usually allowed to recede before supplemental water is introduced. Flow releases during major flood events are made according to established guidelines (USACE, 1995). Lake Okeechobee is connected to the LEC through the major canals. During dry periods, flows from the WCAs and Lake Okeechobee are released to raise canal and groundwater levels. During wet periods, the canal network is used to move runoff to the ocean as quickly as possible.

Lower West Coast

The main canal in the LWC is the Caloosahatchee River (C-43 Canal). It runs from Lake Okeechobee to the Caloosahatchee Estuary. Inflows to the Caloosahatchee River are runoff from the basin and releases from Lake Okeechobee by operation of the S-77 structure according to regulation procedures described by the U.S. Army Corps of Engineers (USACE, 2008). Downstream of S-77 is a gated spillway, S-78, that also receives inflows from the local watershed. The outflow from the Caloosahatchee River (downstream of S-78) is discharged into the estuary via S-79, a gated spillway and lock operated by the USACE. The operations of S-79 include managing stormwater runoff from the Caloosahatchee Watershed. The LWC includes large areas outside the drainage basin of the Caloosahatchee River.

WATER YEAR 2014 HURRICANE SEASON

Atlantic, Gulf of Mexico, and Caribbean tropical activities in WY2014 (2013 hurricane season) were below prediction. A total of 13 events occurred with 11 tropical storms and 2 hurricanes (**Figure 2-3**). In May 2013, NOAA's prediction was a 70 percent chance of 13 to 20 named storms with 7 to 11 becoming hurricanes, including 3 to 6 major hurricanes (http://www.noaanews.noaa.gov/stories2013/20130523_hurricaneoutlook_atlantic.html). On the average, the number of named storms is 12 with 6 hurricanes, including 3 major hurricanes. According to NOAA, 2013 had the fewest number of hurricanes since 1982 and in terms of number of storms, strength and duration, it was the sixth least-active since 1950 (The Palm Beach Post, November 26, 2013).

The season started early with Tropical Storm Andrea forming in the southern Gulf of Mexico on June 3, 2013, as a low pressure system. Andrea made landfall on northwest Florida on June 6, 2013, and then moved into Georgia and later into South Carolina as an extratropical system continuing to the northeast (**Figure 2-3**). It was the only storm that made landfall on the U.S. during the 2013 hurricane season. Tropical Storm Andrea-associated rainfall over the District area is estimated as 4.09 inches from June 3–9, 2013 (**Table 2-3**). Although, the storm passed through North Florida, 8 to 15 inches of rain fell in southeastern Broward and northeastern Miami-Dade counties, with 15 inches registered in North Miami Beach (**Figure 2-4**). Severe flooding was reported in the Miami-Fort Lauderdale metropolitan area (http://www.srh.noaa.gov/bro/?n=2013event_hurricaneseasonwrap). Notably, Tropical Storm Andrea followed a wet May and occurred in a wet June. This created water management challenges especially in the operation of STA-1W, STA-1E, and STA-3/4, where flooding conditions forced diversion of stormwater into the WCAs. Details of this event are covered in an after action report (SFWMD, 2013).

The other two systems that came close to the District region were Tropical System Dorian (July 23–August 3) and Tropical Storm Karen (October 3–6). Dorian was a tropical system that originated from the West African coast. It moved as a tropical depression southeast to east of the District area and contributed some rainfall from August 1 to 3, 2013 (**Table 2-3**). Tropical Storm Karen moved from south to north in the central Gulf of Mexico and likely contributed some rainfall to the southern and southwestern vicinity of the District from October 2 to 4, 2013.

According to NOAA (http://www.srh.noaa.gov/bro/?n=2013event_hurricaneseasonwrap), various causes are suspected to have influenced the low tropical activities for the season. Deep atmospheric shear dominated a good portion of the Main Development Region (MDR) in the Atlantic. Dry air dominated the MDR, Caribbean, and Gulf of Mexico region. A weak sub-Saharan jet stream may have reduced or affected the characteristic of easterly waves leaving from the West African coast. An unusually low monthly index for the Atlantic Multidecadal Oscillation may have contributed to the increased dry air. The negative to positive shift of the North Atlantic Oscillation may have also contributed to the low number of tropical system developments. According to the Weather Underground, although atmospheric phenomenon looked favorable for tropical system development, an unusually strong trough of low pressure over the Central Atlantic brought large amounts of dry air during the season (http://www.wunderground.com/blog/JeffMasters/archive.html?year=2013&month=07). Also, a large amount of dry air from the Sahara and Northeast Brazil, in severe drought, invaded the Atlantic negatively impacting tropical systems development.

Table 2-3. Rainfall from Tropical Storm Andrea, June 3 (7 a.m.) to June 9 (7 a.m.) and Tropical Depression Dorian, August 1 (7 a.m.) to August 4 (7 a.m.), average over rainfall area.

Rainfall Area	Rainfall (in)	
	T.S. Andrea	T.S. Dorian
Upper Kissimmee	4.9	0.64
Lower Kissimmee	4.19	0.87
Lake Okeechobee	3.81	0.67
East Everglades Agricultural Area	5.04	0.62
West Everglades Agricultural Area	3.4	0.67
Water Conservation Areas 1 & 2	5.54	0.6
Water Conservation Area 3	3.89	0.69
Martin/St. Lucie	3.51	0.57
Palm Beach	4.91	0.61
Broward	4.56	0.76
Miami-Dade	2.91	0.4
East Caloosahatchee	4.54	0.54
Big Cypress Basin	3.01	0.27
Southwest Coast	3.78	0.8
SFWMD Spatial Average	**4.1**	0.63

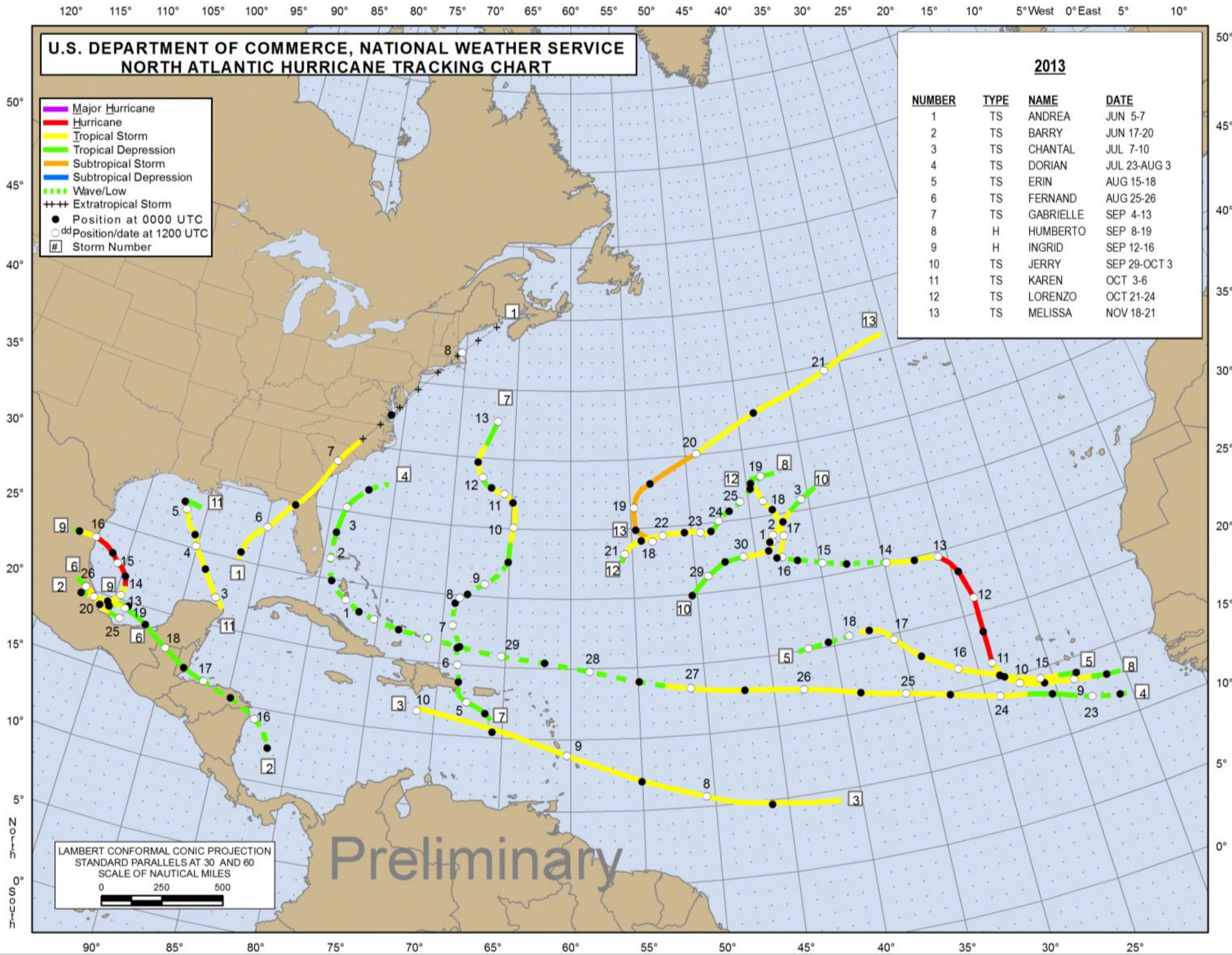


Figure 2-3. 2013 tropical systems tracks and durations (http://www.nhc.noaa.gov/2013atlan.shtml).

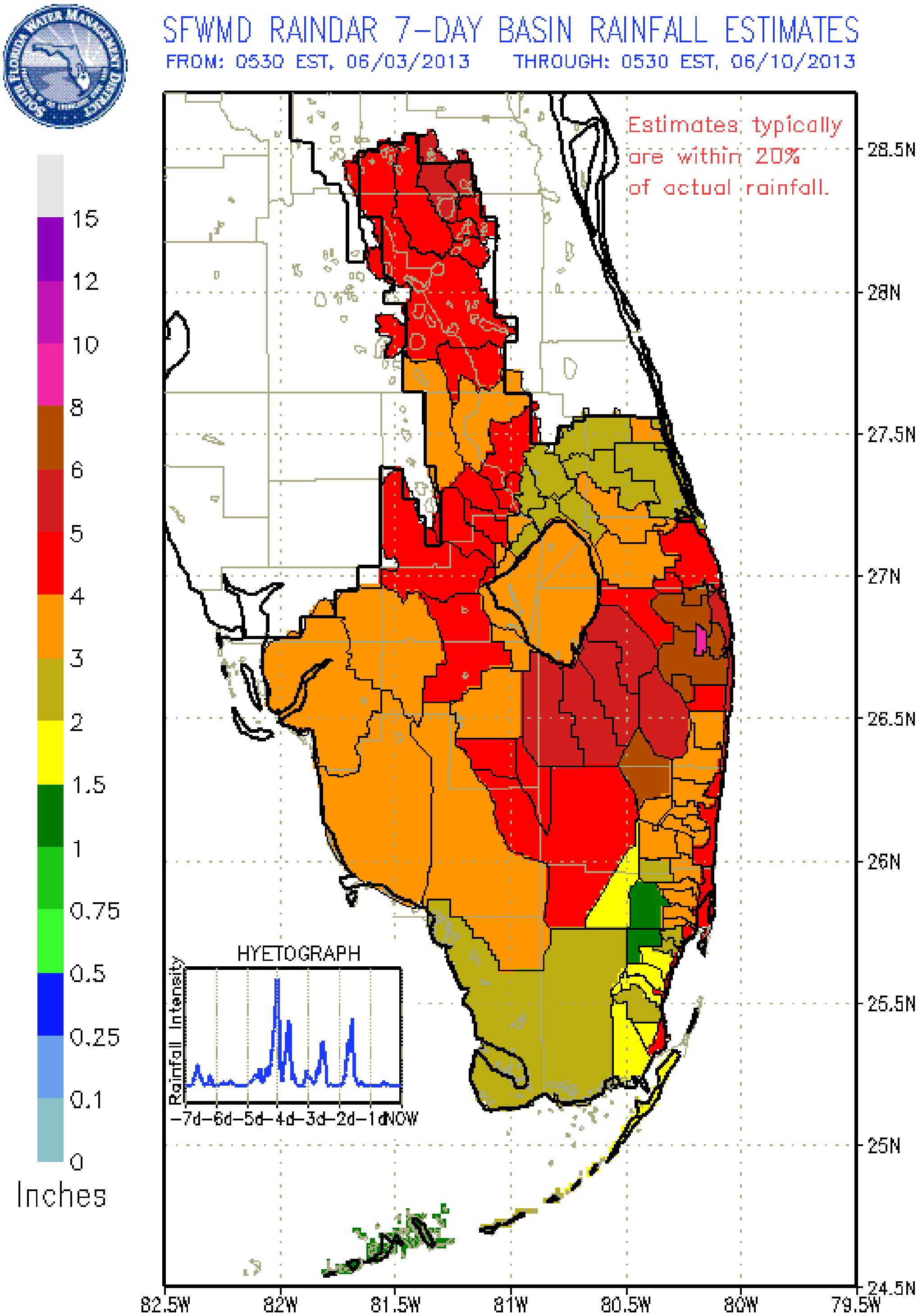


Figure 2-4. Raindar rainfall estimate from Tropical Storm Andrea, June 3 (7 a.m.) to June 10 (7 a.m.).

2013 AND 2014 EL NIÑO SOUTHERN OSCILLATION

The 2012 neutral El Niño Southern Oscillation (ENSO) condition continued to the beginning of 2013, persisting into the spring. Low negative sea surface temperature anomalies in tropical Pacific west of Peru continued to the end of 2013, with the year ending in neutral to weak La Niña condition. The beginning of 2014 stayed the same but warming up started by the end of March. The warming is expected to continue, with an increased chance of El Niño in 2014, as shown with increasing slope of the cumulative sea surface temperature (SST) index tracking plot (**Figure 2-5**). **Figure 2-5** depicts a cumulative SST tracking index where positive values indicate the presence of El Niño and negative values indicate La Niña; values closer to zero indicate a neutral condition (Abtew et al., 2009; Abtew and Trimble, 2010). El Niño conditions create wind shear that weakens Atlantic tropical systems and also influence the path of tropical storms to curve to the north and east away from the land mass of the eastern United States. As a result of the expected El Niño in 2014, the prediction of number of storms is lower than the average; 10 named storms, 4 hurricanes with 1 major hurricane (Klotzbach and Gray, 2014). The hydrology of South Florida during an El Niño year is characterized by high rainfall during the following dry season. La Niña conditions create favorable conditions for Atlantic tropical storms. South Florida dry season rainfall during La Niña years is likely to be below average and cause droughts (Abtew and Trimble, 2010).

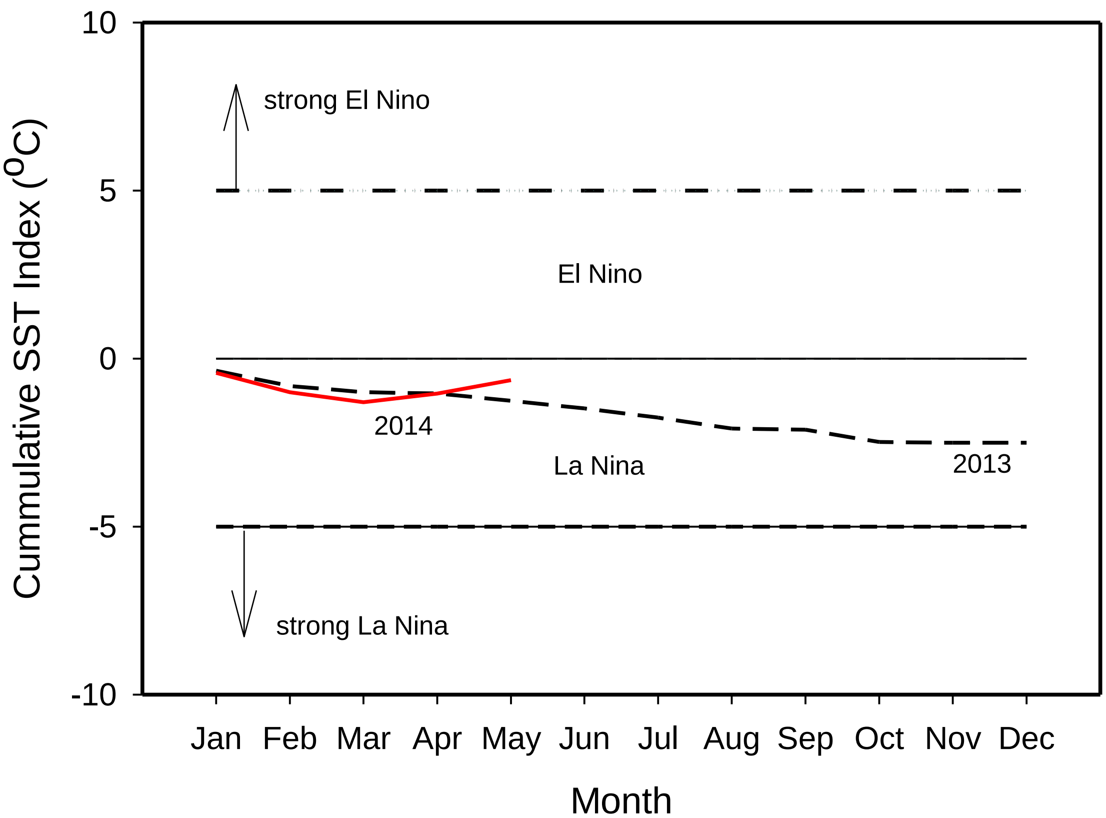


Figure 2-5. Calendar year 2013 and 2014 El Niño Southern Oscillation (ENSO) developments.

WATER YEAR 2014 EXTREME RAINFALL EVENT

JANUARY 9–10 EAST COAST HEAVY RAINFALL EVENT

At the beginning of 2014, the January 9–10 rainfall event on coastal St. Lucie, Martin, and Palm Beach counties was a rare event, with a frequency higher than 100-year one-day maximum rainfall at several sites (**Table 2-4**; **Figure 2-5**). On January 9, afternoon rains concentrated in the north on Martin and St. Lucie counties, and the evening rain concentrated on Palm Beach County. The rain lasted from 1:00 p.m. on January 9 to 7:00 a.m. on January 10. St Lucie and Martin counties rainfall started early and was limited to January 9. Radar rainfall estimates showed intensities of 1.77 inches per 15 minutes and over 3 inches per hour at locations in St. Lucie County Mid-Coastal area. In Martin County, North Folk area radar rainfall estimates showed intensities of 1.75 inches per 15 minutes and over 4 inches per hour. Flash flooding was observed in both counties from as much as 8.81 inches of rainfall observed by a rain gauge.

According to the National Weather Service, the storm was caused when a cold front that passed through the area warmed up and moved back north, while from the east and southeast, warm moist air flow on top of it (The Palm Beach Post, January 13, 2014). The National Weather Service reported more than 22 inches of rainfall in Boynton Beach, which was the hardest hit area (The Palm Beach Post, January 15, 2014). It was also reported that 12 inches of rainfall fell in the first two hours. Rainfall intensity of 2.2 inches in 15 minutes was observed in eastern Palm Beach County in the C-15 basin, with a maximum of over 7 inches in one hour (**Figure 2-6**). In the same basin, radar estimated rainfall of 15.1 inches fell at a site in three and a half hours (**Figure 2-7**). Rainfall of 15.75 inches in less than six hours was reported at the Lake Worth Drainage District (LWDD) office. In St. Lucie County, 8.68 inches of rainfall fell in 4 hours at a location in the mid-coastal area on January 9 (4:00 p.m. to 7:00 p.m.), as shown in **Figure 2-6**. In Martin County, 6.23 inches rainfall fell in four hours at a location in North Folk area (**Figure 2-6**).

The impact of the extreme rainfall resulted in the closing a section of Interstate 95 from Boynton Beach Boulevard to Hypoluxo Road (approximately three miles), street flooding that stranded vehicles, and local school closures. As many as 140 homes in Palm Beach County had flooding (Palm Beach Post, January 14, 2014). The District reported that its primary system water control structure gates were fully open. The tertiary (neighborhood) and secondary (Lake Worth Drainage District, or LWDD) canal systems were overwhelmed with the high intensity of rainfall and associated flash flood. It was noted that the primary drainage system was helped by the fact that the flooding was close to the ocean, making it a short distance to move the flood waters that reached the primary canals. St. Lucie, Martin, and Palm Beach counties were affected.

Notably, a rainfall cell lingered in a small area in North Palm Beach, C-17 basin, and produced high rainfall on January 2 and 3, 1999. The S-44 rain gauge registered 32.53 inches (Ali and Abtew, 1999). This rain gauge rainfall record was assumed to be too high to be true and was revised to 19.54 inches based on field comparison with a manual gauge at different location. Analysis methods such as rainfall-flow correlation, rainfall-groundwater correlation, and basin water budget were performed to estimate the rainfall amount at the basin level. The 1999 and the 2014 extreme rainfall events show that it is possible to get extremely high rainfall at locations near the east coast in the month of January. January average rainfall in the Palm Beach rainfall area is three inches. For the 2014 event, maximum rainfall (in) at a Raindar pixel, return period estimates for maximum one-day rainfall at a site (years), and basin average rainfall for the event are shown in **Table 2-4**.

Table 2-4. Coastal heavy rainfall radar estimates at Raindar pixels* and basin average during the January 9-10 rainfall event.

Basin or Area	Maximum Rainfall at a Location (in)	Return Period (yrs)	Basin Average Rainfall (in)
C-16	22.3	>100	6.0
C-15	23.8	>100	11.7
Coastal_PB_Co	23.5	>100	8.6
C-17	7.9	---	3.7
C-18	9.4	---	4.6
South_Indian_River	8.2	---	6.0
Coastal_Martin_Co	14.2	100	6.9
Coastal_St._Lucie_Co	14.3	100	10.0
North_St._Lucie	14.0	100	5.8

*A Raindar pixel is a 2 km by 2 km area (1.56 sq mi).

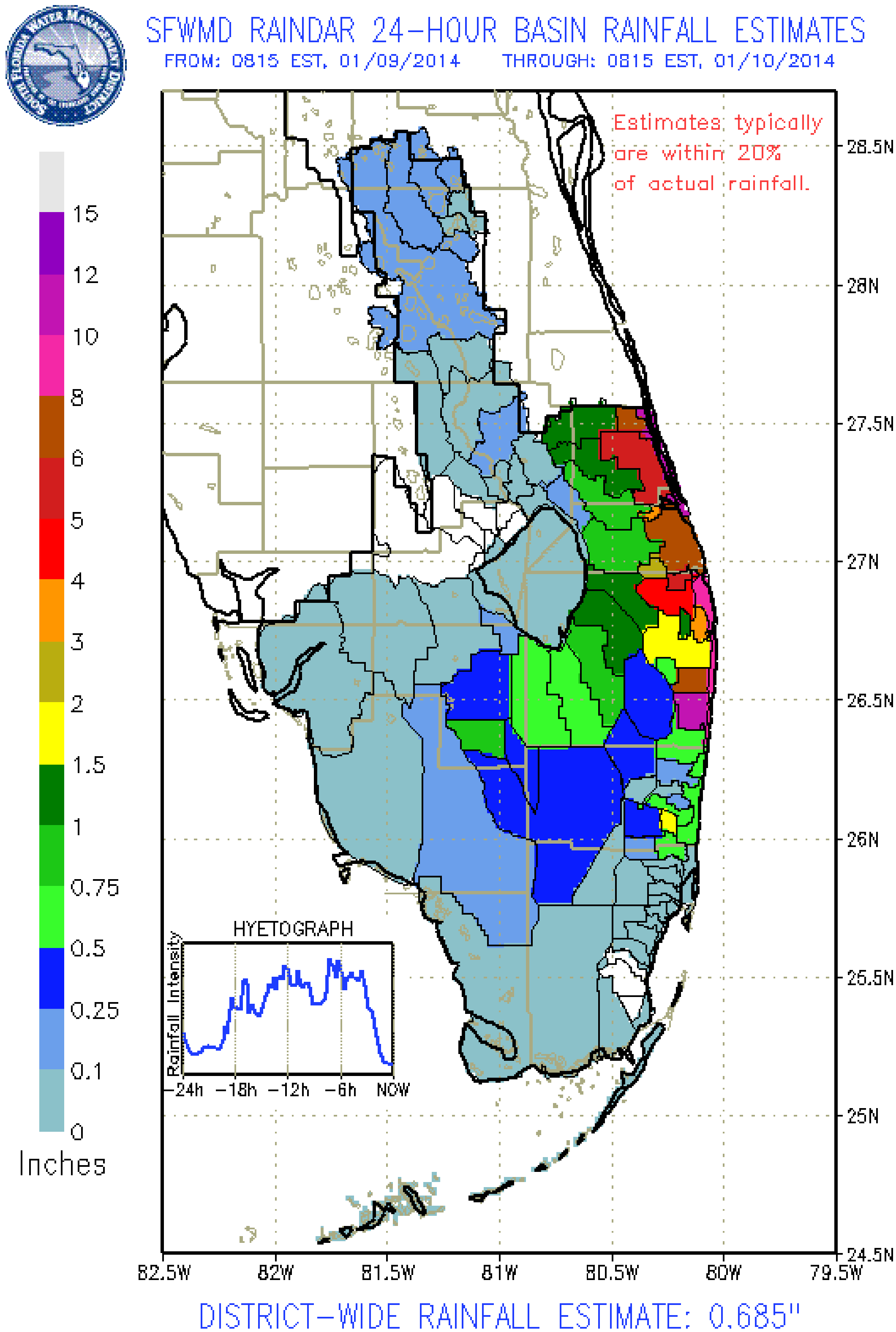


Figure 2-6. Basin average radar rainfall estimates during the January 9–10 rainfall event.

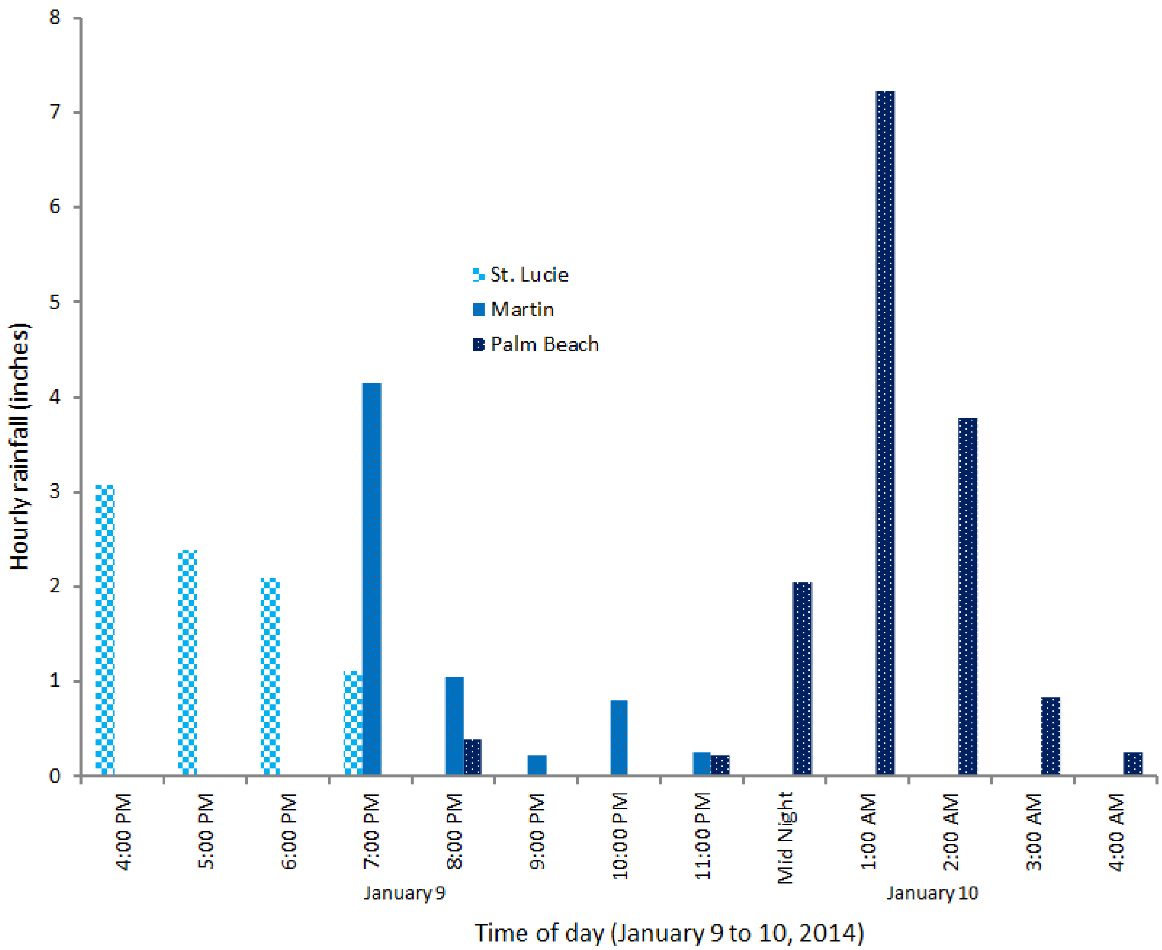


Figure 2-7. Hourly rainfall intensity in eastern St. Lucie, Martin, and Palm Beach counties Raindar pixels from January 9 (4:00 p.m.) to January 10 (4:00 a.m).

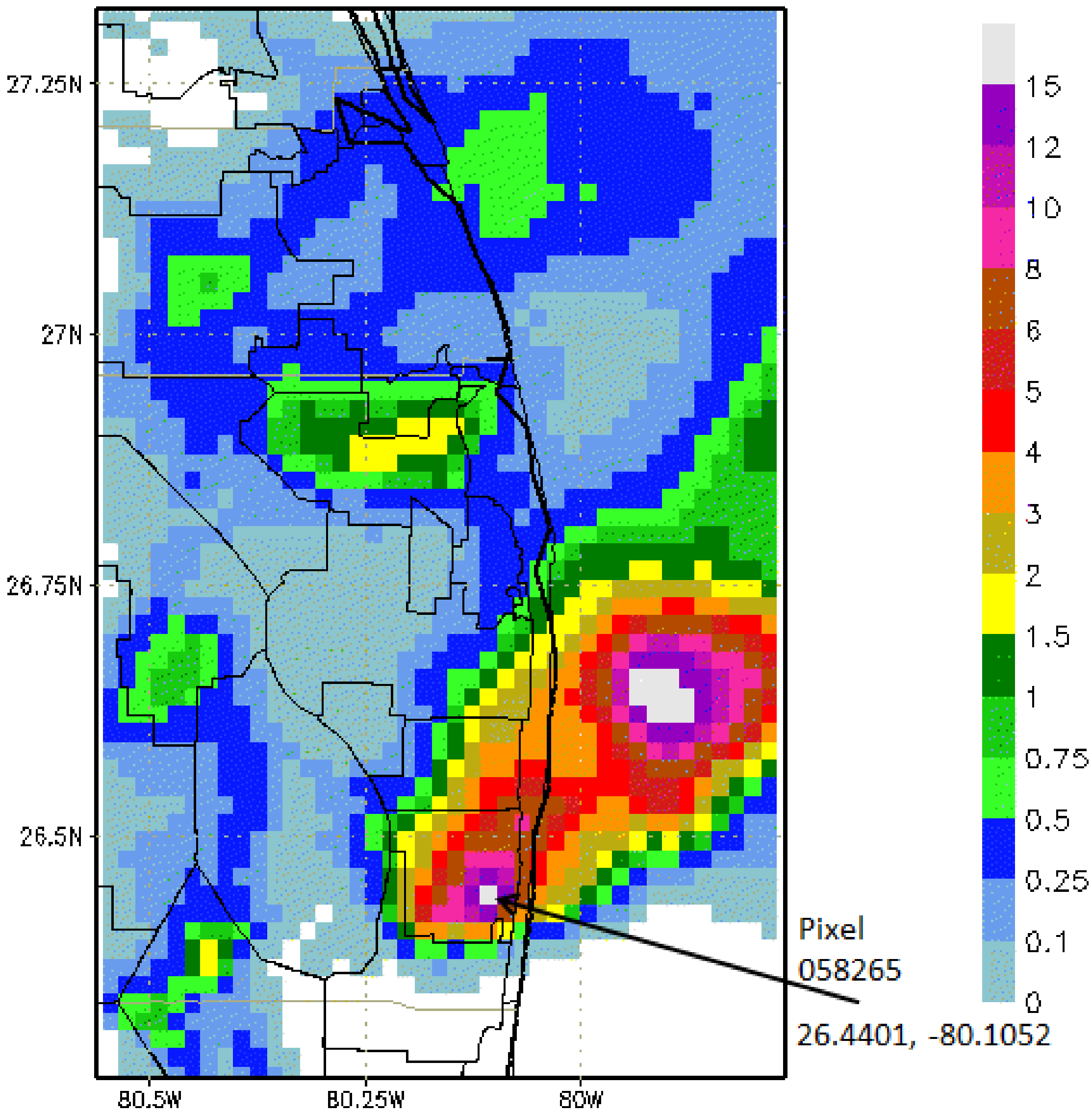


Figure 2-8. Radar rainfall estimate (15.1 in) in a pixel in the C-15 basin from January 9 (10:45 p.m.) to January 10 (2:15 a.m).

WATER YEAR 2014 HYDROLOGY

RAINFALL AND EVAPOTRANSPIRATION

Following the two below average rainfall years of WY2011 and WY2012, hydrologic conditions of South Florida improved with average rainfall in WY2013. WY2014 was wetter than average, with a District average of 55.14 inches compared to annual average of 52.75 inches. The temporal and spatial distribution of the rainfall was uneven when there was flooding at one time and severe drought conditions at another time. Temporally, on the average, six months experienced drier than average rainfall. In most rainfall areas, August, September, and October of the wet season months were drier than average. October was extremely dry in Martin/St. Lucie and Palm Beach rainfall areas. However, June and July from the wet season and May and January from the dry season were wet enough to make up the deficit and drive the District's WY2014 rainfall to above average. Spatially, Lower Kissimmee (+8.88 inches), Broward (+6.73 inches), Southwest Coast (+6.3 inches), WCA-3A (+2.73 inches), Martin/St. Lucie (+2.66 inches), Miami-Dade (+2.42 inches), Lake Okeechobee (+1.97 inches), and WCA-1 and 2 (+1.96 inches) were wetter than normal. West EAA (-6.2 inches), ENP (-5.14 inches), and East EAA (-2.8 inches) experienced drier than average rainfall.

Table 2-5 depicts monthly rainfall for each rainfall area for WY2014. **Table 2-6** presents dry and wet return periods of monthly rainfall in each rainfall area during WY2014, showing each month's state in each area. As shown in **Table 2-6**, on the average, six months were dry months with different return periods. East EAA had eight dry months and West EAA had nine dry months. Although WY2014 tropical storm activity was low, there was considerable contribution of rainfall in June from Tropical Storm Andrea over the District (4.09 inches). Tropical System Dorian in August and Tropical Storm Karen in October also contributed some rainfall.

Regionally, the balance between rainfall and evapotranspiration maintains the hydrologic system in either a wet or dry condition. ETp is potential evapotranspiration or actual evaporation for lakes, wetlands, and any feature that is wet year-round. In South Florida, most of the variation in evapotranspiration is explained by solar radiation (Abtew, 1996; Abtew and Melesse, 2013). Regional estimates of average ETp from open water and wetlands that do not dry out, range from 48 inches in the District's northern section to 54 inches in the Southern Everglades (Abtew et al., 2003; Abtew, 2005). Available ETp data from the closest site to a rainfall area was used to estimate ETp for the area. In WY2014, ETp was lower than rainfall by 3.3 inches, reflecting wetter conditions during this period. **Table 2-7** shows ETp for each rainfall area, ENP, and District average. **Table 2-8** summarizes WY2013, WY2014, and historical average annual rainfall; WY2014 ETp; and WY2014 rainfall anomalies. Appendix 2-1 of this volume compares WY2013 and WY2014 monthly rainfall, historical average rainfall, and WY2014 ETp for each rainfall area.

Table 2-5. WY2014 monthly rainfall (inches) for each rainfall area. [Note: Data from each rainfall area is from the District's operations rainfall database, which accumulates daily rainfall data from 7:00 a.m. of the previous day through 6:59 a.m. of the data registration day, both in Eastern Standard Time; ENP rainfall is the average of eight stations: S-332, BCA20, S-18C, HOMESTEADARB, JBTS, S-331W, S-334, and S-12D.]

Year	Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East Everglades Agricultural Area	West Everglades Agricultural Area	Water Conservation Areas 1,2	Water Conservation Area 3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast	District average	Everglades National Park
2013	May	4.49	5.62	4.79	5.93	3.76	8.04	7.29	7.36	11.06	10.03	9.59	4.27	7.44	4.69	6.31	7.87
2013	June	11.01	10.72	10.43	10.59	11.15	10.53	10.34	8.09	9.91	8.91	6.52	13.36	10.40	13.81	10.68	5.96
2013	July	9.29	12.17	9.15	9.65	9.37	11.55	11.00	9.23	9.50	13.18	11.18	10.36	10.85	10.75	10.36	10.52
2013	Aug	5.81	6.64	5.63	6.10	5.82	4.32	4.92	4.92	4.38	4.03	3.99	8.35	5.91	9.08	6.08	3.91
2013	Sept	6.71	6.91	6.41	5.56	5.33	5.95	6.39	8.87	8.15	6.18	6.40	8.58	7.84	10.37	7.44	6.30
2013	Oct	0.89	0.91	1.54	1.54	1.43	1.39	2.04	0.73	0.81	2.78	3.41	1.37	1.30	1.20	1.39	2.66
2013	Nov	2.18	1.24	0.80	1.26	1.12	2.92	3.17	3.18	3.82	7.13	6.68	0.77	2.24	1.20	2.28	4.00
2013	Dec	0.38	0.28	0.37	0.19	0.34	0.74	0.98	1.14	1.39	1.61	3.62	0.26	0.40	0.37	0.74	1.91
2014	Jan	3.07	3.18	2.53	3.96	3.71	3.39	2.61	6.89	7.02	3.48	2.75	3.03	2.84	3.25	3.60	2.33
2014	Feb	1.47	1.83	1.92	1.75	1.99	1.70	1.90	2.25	1.73	1.97	1.82	1.88	1.29	1.01	1.70	1.61
2014	Mar	3.50	2.27	2.33	2.36	2.31	1.64	1.82	2.15	2.54	2.04	1.88	3.03	1.99	2.70	2.42	1.91
2014	Apr	3.74	1.56	2.04	1.79	2.42	1.75	1.64	1.99	1.72	3.76	1.69	2.15	2.29	1.99	2.14	1.10
Sum	**(inches)**	**52.54**	**53.33**	**47.94**	**50.68**	**48.75**	**53.92**	**54.10**	**56.80**	**62.03**	**65.10**	**59.53**	**57.41**	**54.79**	**60.42**	**55.14**	**50.08**

Table 2-6. WY2014 monthly rainfall dry and wet return periods for each rainfall area (derived from Ali and Abtew, 1999).

Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East EAA	West EAA	WCA 1,2	WCA 3	Martin/St.Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast
May-13	>average	5-yr wet	>average	<5-yr wet	<average	>5-yr wet	≈5-yr wet	>5-yr wet	20-yr wet	10-yr wet	>5-yr wet	average	>average	>average
Jun-13	≈10-yr wet	<10-yr wet	10-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	<5-yr wet	>average	<5-yr dry	≈10-yr wet	<5-yr wet	≈10-yr wet
Jul-13	≈5-yr wet	100-yr wet	>10-yr wet	≈5-yr wet	<5-yr wet	<50-yr wet	>20-yr wet	10-yr wet	>5-yr wet	≈50-yr wet	≈20-yr wet	≈10-yr wet	<5-yr wet	<5-yr wet
Aug-13	<5-yr dry	>average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	>5-yr dry	<10-yr dry	<5-yr wet	5-yr dry	<5-yr wet
Sep-13	≈average	5-yr wet	average	<5-yr dry	<5-yr dry	<average	≈average	>average	≈average	<5-yr dry	<5-yr dry	>average	<average	≈5-yr wet
Oct-13	<10-yr dry	<10-yr dry	5-yr dry	>5-yr dry	5-yr dry	≈10-yr dry	5-yr dry	>50-yr dry	>100-yr dry	>5-yr dry	<5-yr dry	>5-yr dry	>5-yr dry	>5-yr dry
Nov-13	average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	average	>average	>average	≈average	>10-yr wet	<20-yr wet	<average	<5-yr wet	<average
Dec-13	≈10-yr dry	>10-yr dry	>5-yr dry	10-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<10-yr wet	<10-yr dry	5-yr dry	5-yr dry
Jan-14	<5-yr wet	>5-yr wet	<5-yr wet	>5-yr wet	≈5-yr wet	<5-yr wet	>average	>20-yr wet	>10-yr wet	≈5-yr wet	<5-yr wet	>5-yr wet	>average	≈5-yr wet
Feb-14	<5-yr dry	<average	≈average	<average	<average	<5-yr dry	<5-yr dry	<average	<5-yr dry	<average	<average	<average	<5-yr dry	<5-yr dry
Mar-14	>average	<average	<average	<average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	<average	<average	>average	<average	>average
Apr-14	<5-yr wet	<average	<average	<5-yr dry	≈average	<5-yr dry	<5-yr dry	<5-yr dry	<5-yr dry	>average	<5-yr dry	<average	average	<average
dry months	4	6	6	8	9	7	6	5	5	6	7	5	6	5
extreme dry								1	1					
wet months	5	5	4	4	3	4	5	5	3	5	4	6	5	7
extreme wet		1				1	1	1	1	1	1			
≈ average	3		2						2			1	1	
dry = < average														
extreme dry>= 20 yr dry														
wet = > average														
extreme wet >= 20-yr														

Table 2-7. WY2014 monthly potential evapotranspiration (ETp, in inches) for each rainfall area.

Year	Month	Upper Kissimmee	Lower Kissimmee	Lake Okeechobee	East Everglades Agricultural Area	West Everglades Agricultural Area	Water Conservation Areas 1,2	Water Conservation Area 3	Martin/St Lucie	Palm Beach	Broward	Miami-Dade	East Caloosahatchee	Big Cypress Preserve	Southwest Coast	Everglades National Park	District average
2013	May	5.78	5.50	6.03	5.49	5.95	5.56	5.74	5.62	5.49	5.74	5.28	6.06	6.00	5.93	5.42	5.73
2013	June	4.93	4.61	4.91	4.61	4.99	4.73	4.73	4.98	4.61	4.73	4.71	4.87	5.12	4.69	4.79	4.80
2013	July	4.85	4.55	4.43	4.58	5.15	4.56	4.69	4.76	4.58	4.69	4.79	5.05	4.92	4.74	4.98	4.74
2013	Aug	5.47	4.91	5.24	5.18	5.28	5.13	4.91	5.53	5.18	4.91	5.04	5.10	5.44	4.72	4.91	5.15
2013	Sept	4.32	3.85	3.95	4.12	4.19	3.89	3.78	4.28	4.12	3.78	3.94	4.43	4.13	4.06	4.03	4.06
2013	Oct	4.51	4.24	4.27	4.18	4.49	4.26	4.26	4.80	4.18	4.26	4.26	4.71	4.22	4.50	4.24	4.37
2013	Nov	2.79	2.89	3.00	2.79	3.17	2.84	3.11	2.92	2.79	3.11	3.09	3.33	2.97	3.40	3.16	3.02
2013	Dec	2.89	2.89	2.57	2.60	2.86	2.88	2.82	2.76	2.60	2.82	3.17	3.10	2.67	3.14	3.15	2.84
2014	Jan	2.84	2.86	3.16	2.81	2.96	2.92	3.00	2.98	2.81	3.00	3.28	3.08	2.74	3.00	3.21	2.96
2014	Feb	3.37	3.59	4.04	3.75	3.91	3.83	3.83	3.76	3.75	3.83	4.04	4.04	3.84	4.16	4.03	3.84
2014	Mar	4.75	4.66	5.03	4.71	5.06	4.79	4.77	4.96	4.71	4.77	5.31	4.95	5.14	5.18	4.93	4.91
2014	Apr	5.16	5.11	5.60	5.30	5.52	5.40	5.17	5.59	5.30	5.17	5.83	5.64	5.52	5.84	6.04	5.44
Sum	**(inches)**	**51.66**	**49.64**	**52.23**	**50.11**	**53.53**	**50.80**	**50.81**	**52.95**	**50.11**	**50.81**	**52.74**	**54.35**	**52.71**	**53.37**	**52.89**	**51.84**

Table 2-8. WY2014, WY2013, and historical average annual rainfall, WY2014 ETp, and WY2014 rainfall deviation from historical average (in) for each rainfall area.

Rainfall Area	WY2014 Rainfall	WY2013 Rainfall	Historical Average Rainfall	WY2014 ETp	WY2014 Rainfall Deviation
Upper Kissimmee	52.54	47.14	50.09	51.66	2.45
Lower Kissimmee	53.33	52.33	44.45	49.64	8.88
Lake Okeechobee	47.94	47.22	45.97	52.23	1.97
East Everglades Agricultural Area	50.68	51.63	53.48	50.11	-2.8
West Everglades Agricultural Area	48.75	53.34	54.95	53.53	-6.2
Water Conservation Areas 1 & 2	53.92	62.8	51.96	50.8	1.96
Water Conservation Area 3	54.1	56.15	51.37	50.81	2.73
Martin/St. Lucie	56.8	51.84	54.14	52.95	2.66
Palm Beach	62.03	62.6	61.54	50.11	0.49
Broward	65.1	61.23	58.13	50.81	6.97
Miami-Dade	59.53	66.36	57.11	52.74	2.42
East Caloosahatchee	57.41	48.37	50.68	54.35	6.73
Big Cypress Basin	54.79	54.03	54.12	52.71	0.67
Southwest Coast	60.42	50.82	54.12	53.37	6.3
Everglades National Park[1]	50.08	58.49	55.22	52.89	-5.14
SFWMD Spatial Average	**55.14**	**53.17**	**52.75**	**51.84**	**2.39**

[1]ENP historical average rainfall estimates from Sculley (1986).

WILDFIRES

One of drought's impacts on the South Florida environment is conditions that promote and spread wildfires. The size and number of wildfires are generally correlated to dry conditions. Generally, drought years have above average total number of acres burned and number of acres burned per fire. For instance, the area burned by wildfire in 1989, 1990, 2001, and 2007 drought years was high. **Figure 2-9** depicts the number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger from WY1982–WY2014. Mostly, major droughts correspond to larger areas burned by wildfire. The number of acres burned in WY2014 was 22,569 acres. The relatively smaller area reflects the wetter than average rainfall for the water year. The average area burned in a year is 106,934 acres.

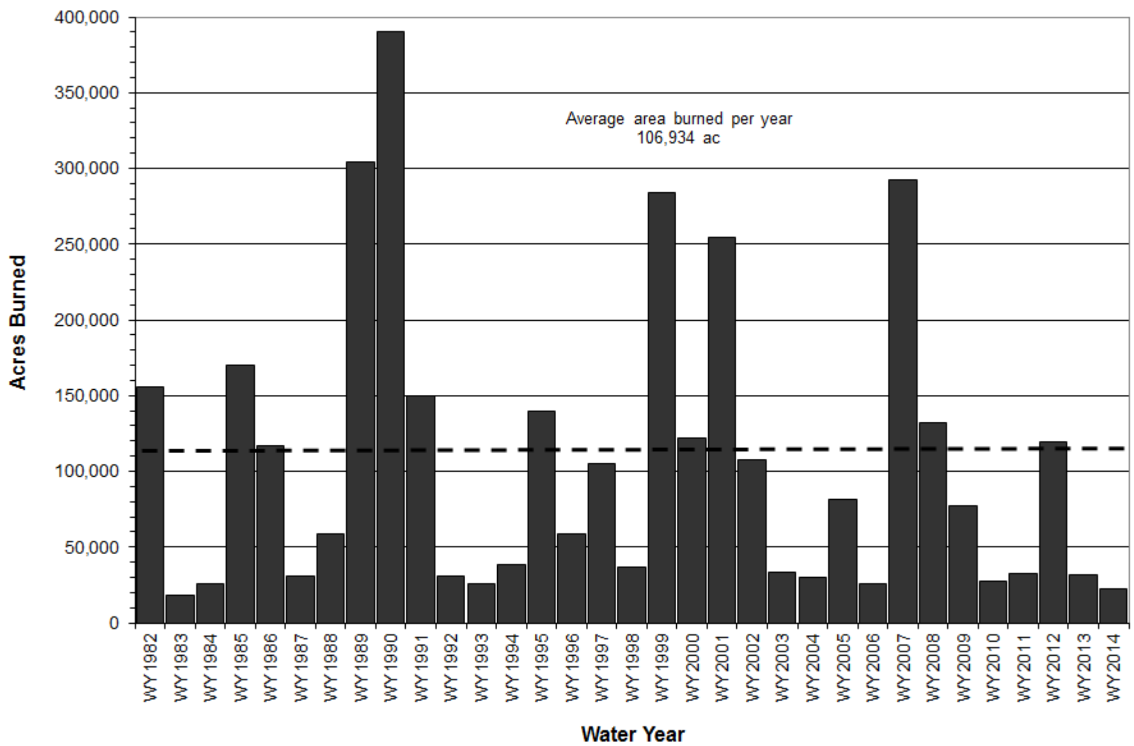


Figure 2-9. Number of acres burned per water year in the SFWMD area from wildfires that were 10 acres or larger (WY1982–WY2014).

GROUNDWATER

The District is divided into four major water resource planning regions (see Appendix 2-2, Figure 1). Each has aquifers that provide water for agricultural, commercial, industrial, and domestic use. The LEC principal groundwater source is the surficial Biscayne aquifer. The UEC principal source of groundwater is the surficial aquifer. The LWC relies on three aquifer systems for water supply, the surficial aquifer system (SAS), the intermediate aquifer system (IAS), and the Floridan aquifer system (FAS). The Lower Tamiami aquifer is part of the SAS; the sandstone and the mid-Hawthorne aquifers are part of the IAS (SFWMD, 2006). The Kissimmee Basin is served by a surficial or shallow aquifer and a deep aquifer, the FAS.

In general, WY2014 groundwater levels in some regions and aquifers were slightly higher, slightly lower, or not different than WY2013, reflecting seasonal hydrology and water demand conditions. Representative groundwater level fluctuation observations from the U.S. Geological Survey are shown in Appendix 2-2 for the stations shown in Figure 1 of that appendix.

WATER MANAGEMENT IN WATER YEAR 2014

OVERVIEW

District-wide water management operations depend largely on the spatial and temporal distribution of rainfall across the South Florida region and antecedent conditions. Although water management of SFWMD facilities is performed according to prescribed operation plans, there are various constraints that are considered while developing and implementing shorter-term operating strategies. Flood control operations are conducted in the wet season and tropical storm events occur in this season. Inflow and outflow operations were regularly conducted to bring water levels of the major water bodies closer to the respective regulation schedules. The water management system was operated in water supply mode for several months when rainfall was below average. From the wet season, October was dry with extreme drought in Martin/St. Lucie and Palm Beach rainfall areas. The dry season months were drier than average, except for May 2013 and January 2014 which made up the deficit (**Table 2-6**).

Water management is performed by using previously established regulation schedules that integrate different purposes. Regulation schedules are rule curves designed to manage the regional storage. In order to broadly satisfy flood control and water supply needs on a long-term basis, daily water level regulation schedules for each of the regional water bodies were developed by USACE and the District in cooperation with other agencies and stakeholders. The regulation schedules for the regional lakes and WCAs are published in detail in the 2007 SFER – Volume I, Appendix 2-6 (Abtew et al., 2007b). At times, deviations from the regular regulation schedules are made for a specific lake or WCA to manage water under particular infrastructural, environmental, or weather-related conditions. For WY2014, temporary operational modifications were established for some of the Kissimmee Chain of Lakes in the Upper Basin to protect and enhance snail kite breeding habitat.

Initiated in May 2008, the current regulation schedule for Lake Okeechobee, known as LORS2008 (USACE, 2008), incorporates current and future (outlook) climatic information in the decision making process. The regulation schedule has three main bands (**Figure 2-10**): High Lake Management Band, Operational Band, and Water Shortage Management Band. The Operational Band is further divided into high, intermediate, low, base flow, and beneficial use categories. In the High Lake Management Band, large flood control releases may be required and outlet canals may be maintained above their optimum water management elevations. In the Operational Band, substantial flood control releases may be implemented; outlet canals should be maintained within their optimum water management elevations. In the Water Shortage Management Band, outlet canals may be maintained below optimum water management elevations and water supply releases from the lake are restricted according to the severity of prolonged dry climate conditions. More information on LORS2008 is also presented in the *Lake Okeechobee* section of this chapter.

Water supply releases are made for various beneficial uses that include water supply for municipal and industrial use, irrigation for agriculture, deliveries to the ENP, salinity control, estuarine management and other environmental releases. Releases are made to the St. Lucie Canal and Caloosahatchee River to maintain navigation depths if sufficient water is available in Lake Okeechobee. The outflows from Lake Okeechobee are received by the St. Lucie Canal, Caloosahatchee River, EAA, Lower East Coast, and in some cases, the WCAs and STAs. **Figure 2-10** depicts Lake Okeechobee daily water level, regulation schedule, and water management decisions. Based on the lake water level and other relevant factors, various water management decisions are depicted on the figure. Release from the lake through S-308 into the St. Lucie Canal, which discharges into the St. Lucie Estuary through S-80; releases from the lake through S-77 and into the Caloosahatchee River, which discharges into the Caloosahatchee Estuary through S-79; and regulatory releases to WCAs are also shown on the figure. Further details of these sub-region flows are provided in the *Water Levels and Flows* section of this chapter.

During WY2014, water managers, scientists, and engineers from the District, USACE, and other federal and state agencies met weekly to discuss the state of the regional system and possible operational scenarios. Reports on the ecological and hydrological status of various areas (e.g., Kissimmee Basin, Lake Okeechobee, St. Lucie and Caloosahatchee estuaries, STAs, Everglades, water supply, and groundwater conditions) were presented. How well the objectives of the Central and South Florida Flood Control Project (water supply, flood control, and protection of fish and wildlife) were met was also discussed. Meeting starts with the previous week's weather report and coming week's rainfall predictions, followed by the climate forecast. The previous week's Lake Okeechobee operations and the rest of the water management system were reported in each meeting. Operational recommendations were given to District managers for approval and then submitted to the USACE in a Weekly Environmental Conditions for Systems Operations memoranda.

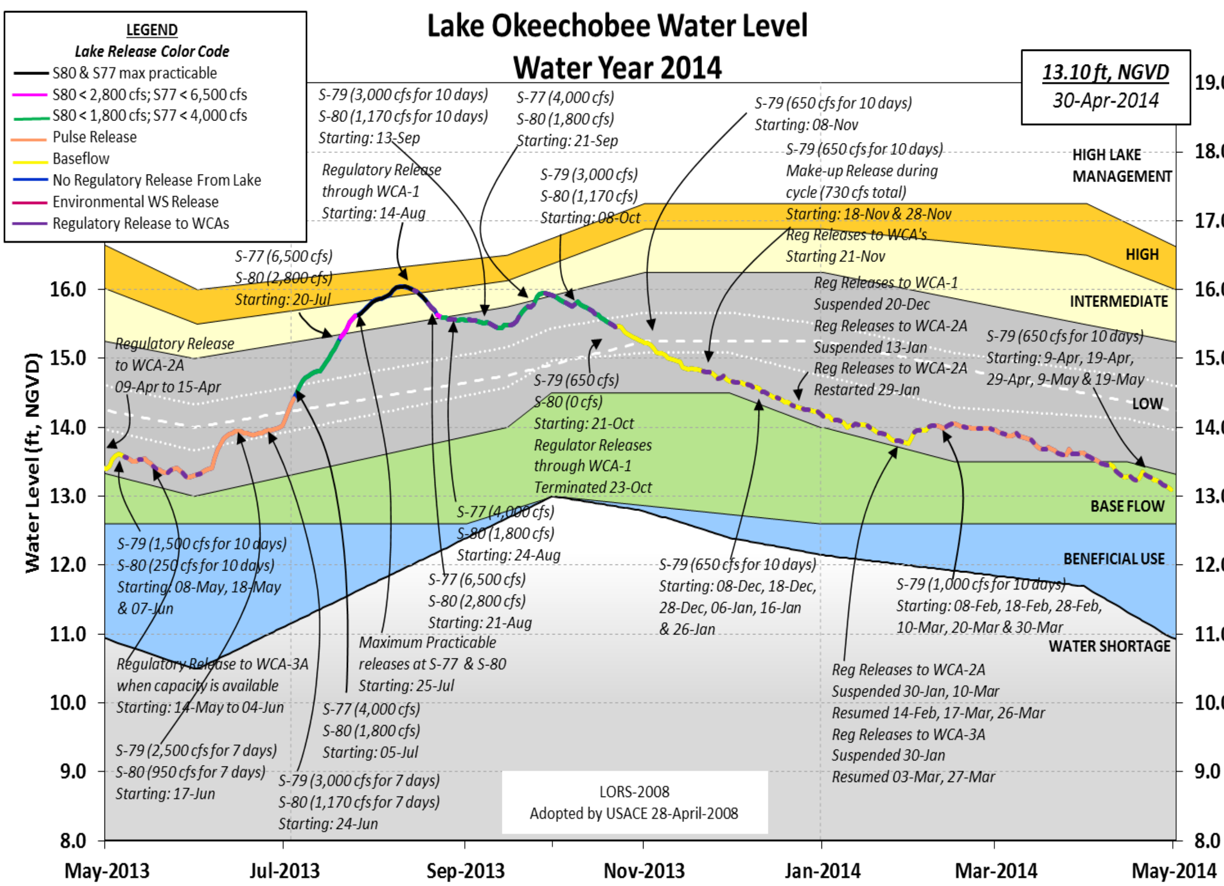


Figure 2-10. Daily Lake Okeechobee water levels, regulation schedule, and water management decisions.

In WY2014, there was no major tropical system event. In June, Tropical Storm Andrea created local flooding in the southeast. The January 2014 east coast extreme rainfall event also created local flooding. Lake Okeechobee was at 13.44 ft NGVD on May 1, 2013, at the start of the WY2014. The lake level rose to a maximum of 16.05 ft NGVD by August 10, 2013, from runoff generated by the above average rainfall of the previous months. Eighty one percent of the water year inflow to the lake was received in four months (June to September).

WATER LEVELS AND FLOWS

For parts of the WY2014 wet and dry seasons, most water control structures were operated for water supply during dry conditions and flood control operations during the wet season and other high rainfall events. Period of record (POR) daily mean water levels (stage) graphs for the lakes, impoundments, and ENP are shown in Appendix 2-3. All water levels are expressed in ft NGVD in these and related publications. **Table 2-9** depicts WY2014, WY2013, and historical mean, maximum, and minimum stages. WY2014 water levels were generally higher than the historical average. WY2014 average water levels were generally similar to WY2013 average levels except for East Lake Tohopekaliga, Lake Kissimmee, Lake Okeechobee, WCA-1 and 2, and ENP levels. The average Lake Okeechobee water level was 0.63 ft higher than WY2013 and 0.46 ft higher than the historical average. Comparison of monthly historical averages, WY2013, and WY2014 water levels are shown in Appendix 2-4. Water levels are also a measure of the amount of stored water. Relationships of water levels (stage) and storage for lakes and impoundments are presented in the 2007 SFER – Volume I, Appendix 2-2.

WY2014 surface water flow statistics were also compared to WY2013 and historical flow records (**Table 2-10**). WY2014 flows were higher than WY2013 flows, except for WCA-1 outflow, WCA-2 inflow, and S-49 discharge. Water bodies' flows were generally much higher than the respective historical average flows, except WCA-1 inflow and S-49 discharge. **Table 2-10** depicts WY2014, WY2013, and historical flow statistics for major impoundments and canals. Monthly flows by structure are shown in Appendix 2-5. Comparison of historical, WY2013, and WY2014 monthly flows is shown in Appendix 2-6. Maps showing water control structures, canals, water bodies, and hydrologic units are available in previous SFERs.

Table 2-9. WY2014, WY2013, and historical stage statistics for regional major lakes and impoundments.

Lake or Impoundment	Beginning of Record	Historical Mean Stage (ft NGVD)	WY2014 Mean Stage (ft NGVD)	WY2013 Mean Stage (ft NGVD)	Historical Maximum Stage (ft NGVD)	Historical Minimum Stage (ft NGVD)
Alligator Lake	1993	62.58	63.03	63.04	64.33	58.13
Lake Myrtle	1993	60.85	61.00	61.05	65.22	58.45
Lake Mary Jane	1993	60.08	60.05	60.26	62.16	57.19
Lake Gentry	1993	60.70	60.92	60.94	61.97	58.31
East Lake Tohopekaliga	1993	56.62	56.56	56.46	59.12	54.41
Lake Tohopekaliga	1993	53.72	53.72	53.75	56.63	48.37
Lake Kissimmee	1929	50.38	50.67	50.44	56.64	42.87
Lake Istokpoga	1993	38.77	38.91	38.89	39.78	35.84
Lake Okeechobee	1931	14.02	14.48	13.85	18.77	8.82
Water Conservation Area 1	1953	15.66	16.31	16.49	18.16	10.00
Water Conservation Area 2A	1961	12.52	12.69	12.45	15.64	9.33
Water Conservation Area 3A	1962	9.59	10.23	10.24	12.79	4.78
Everglades National Park, Slough	1952	6.01	6.63	6.52	8.08	2.01
Everglades National Park, Wet Prairie	1953	2.17	3.24	2.99	7.10	-2.69

Table 2-10. WY2014, WY2013, and historical flow statistics for major impoundments, lakes, and canals.

Lake, Impoundment, Canal	Beginning of Record	Historical Mean Flow (ac-ft)	WY2014 Flow (ac-ft)	Percent of Historical Mean	WY2013 Flow (ac-ft)	Historical Maximum Flow (ac-ft)	Historical Minimum Flow (ac-ft)
Lake Kissimmee Outflow	1972	705,837	765,563	108%	439,653	2,175,297	16,195
Lake Istokpoga Outflow	1972	217,379	319,317	147%	280,544	637,881	26,559
Lake Okeechobee Inflow	1972	2,071,053	2,695,257	130%	2,100,036	4,905,838	377,671
Lake Okeechobee Outflow	1972	1,426,661	2,527,633	177%	1,041,902	3,978,904	176,566
St. Lucie (C-44 Canal) Inflow at S-308	1972	256,774	444,651	173%	103,622	1,117,159	4,061
St. Lucie (C-44 Canal) Outflow at S-80	1972	307,723	675,800	220%	152,722	1,192,782	0
Caloosahatchee River (C-43 Canal) Inflow at S-77	1972	528,989	1,225,613	232%	501,374	2,175,765	42,301
Caloosahatchee River (C-43 Canal) Outflow at S-79	1972	1,234,147	2,521,600	204%	1,137,904	3,655,257	86,895
Water Conservation Area 1 Inflow	1972	474,472	380,269	80%	363,897	1,307,517	152,641
Water Conservation Area 1 Outflow	1972	442,150	471,206	107%	483,713	1,433,399	14,812
Water Conservation Area 2 Inflow	1972	640,108	1,078,408	168%	1,074,320	1,754,710	113,225
Water Conservation Area 2 Outflow	1972	641,551	965,358	150%	938,199	1,729,168	93,564
Water Conservation Area 3A Inflow	1972	1,174,722	1,248,362	106%	1,322,042	2,177,198	393,233
Water Conservation Area 3A Outflow	1972	1,010,336	1,452,583	144%	1,225,088	2,581,129	245,951
Everglades National Park Inflow	1972	988,849	1,590,971	161%	1,496,719	2,838,481	165,372
Upper East Coast C-23 Canal Outflow at S-48	1995	127,187	169,437	133%	85,778	297,214	33,644
Upper East Coast C-24 Canal Outflow at S-49	1972	133,404	107,679	81%	125,826	274,827	10,591

Kissimmee Chain of Lakes

The Upper Kissimmee Basin is an integrated system of several lakes with interconnecting canals and flow control structures (Abtew et al., 2011). The major lakes are shallow with depths from 6 to 13 ft (Guardo, 1992). The Upper Kissimmee Basin structures are operated according to regulation schedules. The details of the water control plan for the Kissimmee River are presented in the Master Water Control Manual for Kissimmee River – Lake Istokpoga (USACE, 1994). Average stage for WY2014, WY2013, and historical observation statistics for the Kissimmee Chain of Lakes are shown in **Table 2-9**. Historical daily water levels are shown in Appendix 2-3. Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4. In WY2014, the Upper Kissimmee Basin produced above average flow volume (765,563 ac-ft), which was 108 percent of the historical average. Monthly inflows and outflows by structure are shown in Appendix 2-5. Appendix 2-6 depicts monthly historical average, WY2014 and WY2013 flows for each water body or canal.

Alligator Lake

The outflows from lakes Alligator, Center, Coon, Trout, Lizzie, and Brick are controlled by two structures: S-58 and S-60. S-58 is located in the C-32 canal that connects lakes Trout and Joel, and S-60 is located in C-33 canal between Alligator Lake and Lake Gentry. Culvert S-58 maintains stages in Alligator Lake upstream from the structure, while the S-60 spillway is operated to main the optimum lake-wide stage. These lakes are regulated between elevations 61.5 and 64.0 ft NGVD on a seasonally varying schedule. Daily water level observations for Alligator Lake over the last 21 years show that the most significant change in water levels occurred during the 2000–2001 drought, with water levels showing a big drop (Appendix 2-3, Figure 1). Generally, water level was below the regulation schedule for part of the year. **Figure 2-11**, panel a, shows the WY2014 daily average stage at the headwater of S-60, daily rainfall, and flood regulation schedule for Alligator Lake. Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 1.

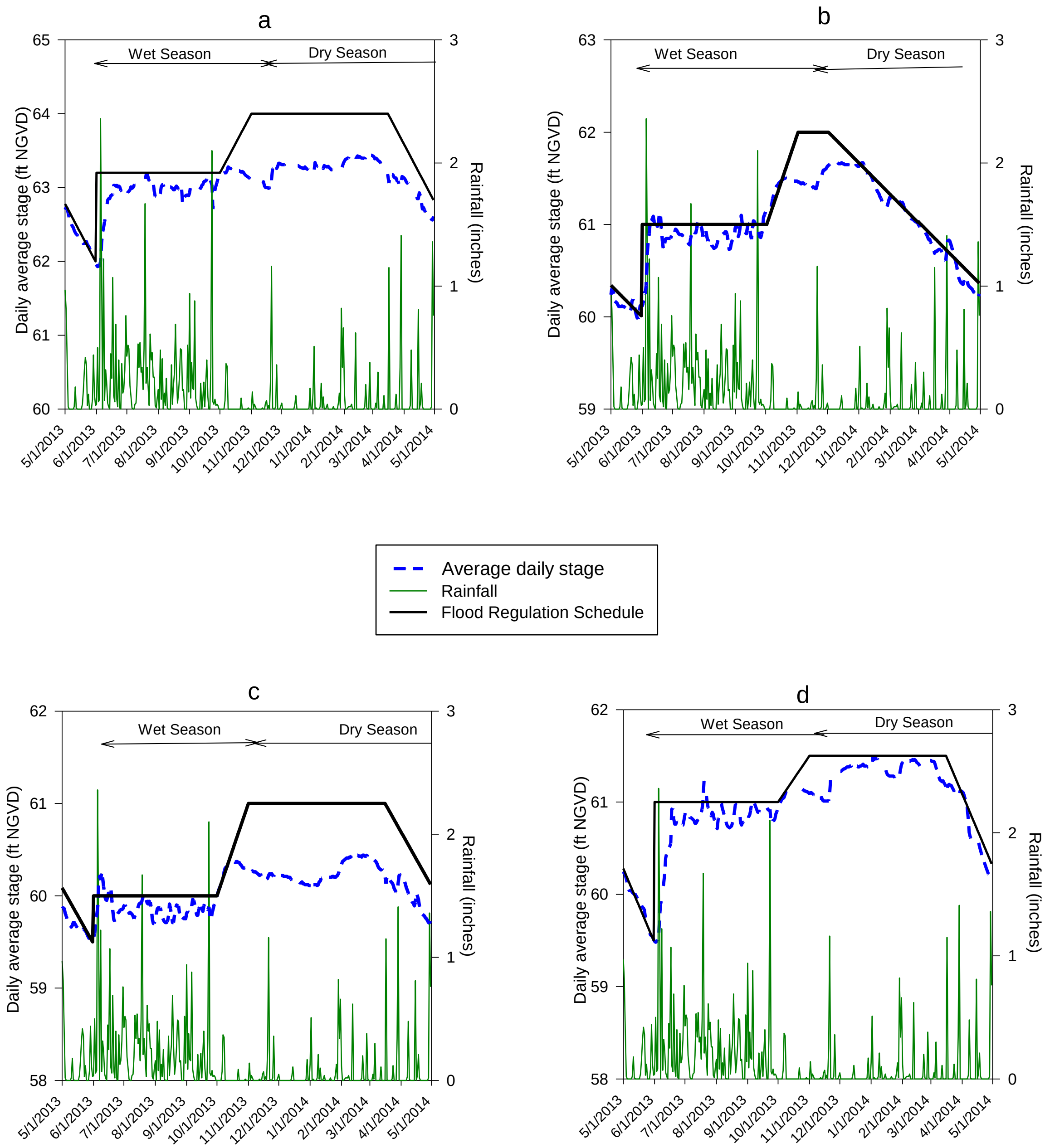


Figure 2-11. Average daily water levels (stage), regulation schedule, and rainfall for (a) Alligator Lake, (b) Lake Myrtle, (c) Lake Mary Jane, and (d) Lake Gentry.

Lakes Joel, Myrtle and Preston

Lakes Joel, Myrtle, and Preston are regulated by structure S-57. The S-57 culvert is located in the C-30 canal that connects Lakes Myrtle and Mary Jane. The lakes are regulated between 59.5 and 62.0 ft NGVD on a seasonally varying schedule. **Figure 2-11**, panel b, shows the WY2014 daily average stage at the headwater of S-57, daily rainfall, and regulation schedule for Lake Myrtle. The stages were mostly following the regulation schedule. Daily water level observations for Lake Myrtle over the last 21 years show that the most significant drop in water level occurred in 2000-2001 and 2010-2011 drought years (Appendix 2-3, Figure 2). Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 2.

Lakes Hart and Mary Jane

Lakes Hart and Mary Jane are regulated by structure S-62. The S-62 spillway is located in the C-29 canal that discharges into Lake Ajay. The lakes are regulated between elevations of 59.5 and 61.0 ft NGVD according to a seasonally varying schedule. **Figure 2-11**, panel c, shows the WY2014 daily average stage at the headwater of S-62, daily rainfall, and flood regulation schedule for Lake Mary Jane. The stages were below the regulation schedule part of the year. Flow releases were made based on water supply needs and flood control. Daily water level observations for Lake Mary Jane over the last 21 years show that the most significant drop in water level occurred in May 2001 during a severe drought year (Appendix 2-3, Figure 3). Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 3.

Lake Gentry

Lake Gentry is regulated by the S-63 structure, located in the C-34 canal at the south end of the lake. The stages downstream of S-63 are further lowered by S-63A before the canal discharges into Lake Cypress. The lake is regulated between elevations of 59.0 and 61.5 ft NGVD according to a seasonally varying schedule. **Figure 2-11**, panel d, shows the WY2014 daily average stage at the headwater of the S-63 spillway, daily rainfall, and flood regulation schedule for Lake Gentry. The stages were generally close to the regulation schedule. Daily water level observations for Lake Gentry over the last 21 years show the most drop in water level occurred in May 2001 during a severe drought year (Appendix 2-3, Figure 4). Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 4.

East Lake Tohopekaliga

East Lake Tohopekaliga and Lake Ajay are regulated by structure S-59, located in the C-31 canal between East Lake Tohopekaliga and Lake Tohopekaliga. The lakes are maintained between 54.5 and 58.0 ft NGVD on a seasonally varying schedule. A weir structure was built downstream of the S-59 spillway to control the tailwater elevation at S-59. The weir crest is at an elevation of 51.0 ft NGVD. The weir is often submerged and therefore, the tailwater influences the headwater of S-59. **Figure 2-12**, panel a, shows the WY2014 daily average stage at the headwater of S-59, daily rainfall, regulation schedule, and ecological regulation schedule for East Lake Tohopekaliga. The stages mostly followed the ecological regulation schedule. Flow releases were based on water supply needs, flood control and maintaining the regulation schedule whenever possible. Daily water level observations for East Lake Tohopekaliga in the last 21 years are shown in Appendix 2-3, Figure 5. Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 5.

Lake Tohopekaliga

Lake Tohopekaliga is regulated by structure S-61, located in the C-35 canal at the south shore of the lake. The lake is regulated between the elevations of 51.5 and 55.0 ft NGVD on a seasonally varying schedule. The S-61 structure is used to maintain the optimum stage in Lake Tohopekaliga. **Figure 2-12**, panel b, shows the WY2014 daily average stage at the headwater of S-61, daily rainfall, regulation schedule, and ecological regulation schedule for Lake Tohopekaliga. The stages mostly followed the ecological regulation schedule. Daily water level observations for Lake Tohopekaliga over the last 21 years show the most significant drop in water level occurred in June 2004 during the lake drawdown (Appendix 2-3, Figure 6). Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 6.

Lakes Kissimmee, Hatchineha and Cypress

Lakes Kissimmee, Hatchineha, and Cypress are regulated by the S-65 spillway and lock structure located at the outlet of Lake Kissimmee and the head of the Kissimmee River (C-38 canal). Lake Kissimmee covers approximately 35,000 acres and is regulated between 48.5 and 52.5 ft NGVD on a seasonally varying schedule. **Figure 2-12** (panel c) shows the daily average stage at the headwater of S-65, daily rainfall, regulation schedule, and ecological regulation schedule for Lake Kissimmee during WY2014. The stages mostly followed the ecological regulation schedule. Releases were made based on downstream water needs and flood control. Appendix 2-3, Figure 7 shows daily water level for 1929–2014. Monthly historical average, WY2014, and WY2013 water levels for the lakes are shown in Appendix 2-4, Figure 7.

The Upper Kissimmee Basin received above average rainfall (+2.45 inches) resulting in above average discharge out of Lake Kissimmee, 765,563 ac-ft, 108 percent of historical average. There has been discharge from Lake Kissimmee to the Kissimmee River throughout the water year except three days in June 2013. **Table 2-10** depicts WY2014, WY2013 and historical flow statistics for major impoundments. WY2014 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2013, and WY2014 flows are presented in Appendix 2-6, Figure 1.

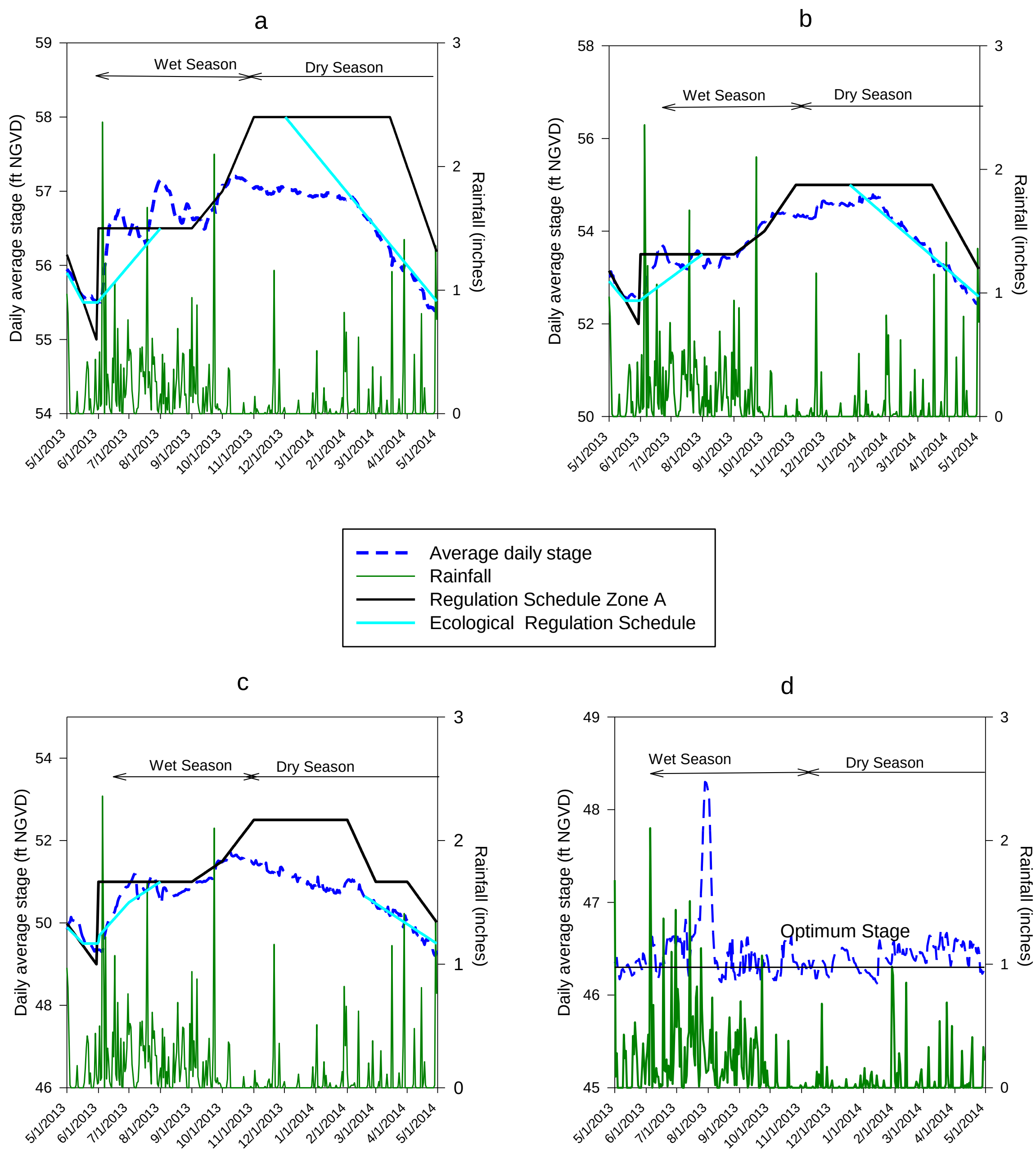


Figure 2-12. Average daily water levels (stage), regular regulation schedule, temporary modifications and rainfall for (a) East Lake Tohopekaliga, (b) Lake Tohopekaliga, (c) Lake Kissimmee, and (d) Pool A.

Lower Kissimmee System

The Lower Kissimmee System consists of the Kissimmee River (C-38 canal) and four structures (S-65A, S-65C, S-65D, and S-65E) that form four pools (A, C, D, and E). These structures are operated according to optimum stages. Optimum stages for S-65A, S-65C, S-65D, and S-65E are 46.3, 34.4, 26.8, and 21.0 ft NGVD, respectively (Abtew et al., 2011). WY2014 conditions in the Kissimmee River system are covered in detail in Chapter 9 of this volume.

Pool A

Stages in Pool A are controlled by the S-65A gated spillway and lock, and the pool is downstream of the S-65 structure. In addition to S-65A, a culvert structure is located through the east tieback levee at the natural channel of the Kissimmee River. During water supply periods, minimum releases are made to satisfy water demands and maintain navigation downstream. The culvert also provides water to the oxbows of the natural river channel. **Figure 2-12**, panel d, shows the daily average stage at the headwater of S-65A, daily rainfall, and optimum stage for Pool A during WY2014. There was a brief spike in water level of more than 2 ft in July 2013 when upstream discharge from Lake Kissimmee through the S65 structure was high. Otherwise, stages remained around the optimum stage of 46.3 ft NGVD for the water year.

Pool C

Stages in Pool C are controlled by the S-65C gated spillway and lock, which is downstream of the S-65A structure. In addition to S-65C, there is a culvert structure that is located through the east tieback levee at the natural channel of the Kissimmee River. During WY2014, minimum and maximum headwater stages at S-65C were 32.73 and 35.71 ft NGVD, respectively, with mean stage of 34.00 ft NGVD.

Pool D

Stages in Pool D are controlled by the S-65D gated spillway and lock downstream of S-65C. During WY2014, headwater stages at S-65D ranged from 27.21 to 27.57 ft NGVD with mean stage of 27.42 ft NGVD.

Pool E

Stages in Pool E are controlled by the S-65E gated spillway and lock, which is downstream of the S-65D. During WY2014, minimum and maximum headwater stages at S-65E were 20.84 and 21.17 ft NGVD, respectively with mean stage of 20.01 ft NGVD.

Lake Istokpoga

Lake Istokpoga has a surface area of approximately 27,700 acres. Stages in Lake Istokpoga are maintained in accordance with a regulation schedule that varies seasonally. The S-68 spillway, located at the south end of the lake, regulates the lake stage and discharges water to the C-41A canal (the Slough Canal). The C-41 canal (Harney Pond Canal), the C-40 canal (Indian Prairie Canal), and the C-39A canal (State Road 70 Canal) provide secondary conveyance capacity for the regulation of floods in the Lake Istokpoga Water Management Basin. The C-40 and C-41 canals flow into Lake Okeechobee, whereas the C-41A canal flows into the Kissimmee River which flows into Lake Okeechobee. Details of Lake Istokpoga water control plan are available in the Master Water Control Manual for Kissimmee River – Lake Istokpoga Basin (USACE, 1994).

Figure 2-13, panel a, shows the daily average stage at the headwater of S-68, daily rainfall, and regulation schedules for Lake Istokpoga during WY2014. Appendix 2-3, Figure 8, shows daily water levels for the period from 1993–2014. Generally, the stages were close to the regulation schedule. Minimum releases, based on water supply needs, were made during drier periods and flood control releases during wet periods. WY2014 flows (319,317 ac-ft) were 147 percent of the historical average and 114 percent of WY2013. **Table 2-10** depicts WY2014, WY2013 and historical flow statistics for major impoundments. WY2014 monthly flows are shown in Appendix 2-5, Table 1. Monthly historical average, WY2013, and WY2014 flows are presented in Appendix 2-6, Figure 2.

Lake Okeechobee

Lake Okeechobee's water level is regulated to provide (1) flood control, (2) navigation, (3) water supply for agricultural irrigation, municipalities and industry, the EPA and the STAs, (4) regional groundwater control, (5) salinity control, (6) enhancement of fish and wildlife, and (7) recreation (Abtew et al., 2011). The regulation schedule accounts for varying and often conflicting purposes. The lake was regulated under a different regulation schedule in previous water years (Abtew et al., 2007b). An updated regulation schedule was adopted on April 28, 2008, for Lake Okeechobee, which was implemented on May 1, 2008 (USACE, 2008). Details of the current regulation schedule are discussed below and shown in **Figure 2-14**.

Lake Okeechobee has an approximate surface area of 436,300 acres at the historical average stage of 14.02 ft NGVD (1931–2014). At the beginning of the water year, the lake stage was 13.44 ft NGVD and the average stage was 14.48 ft NGVD for the water year almost half ft higher than the historical average. Stage at the end of the water year was 13.07 ft NGVD. **Figure 2-13** (panel b) shows the daily average stage and daily rainfall for Lake Okeechobee during WY2014. Appendix 2-3, Figure 9, shows daily water levels for Lake Okeechobee for the period of record, 1931–2014. Monthly historical average, WY2013, and WY2014 water levels are shown in Appendix 2-4, Figure 9. **Table 2-9** depicts WY2014, WY2013, and historical mean, maximum and minimum stages.

WY2014 inflows into Lake Okeechobee (2,695,257 ac-ft) were high, 130 percent of the historical average inflows (2,071,053 ac-ft). WY2014 outflows of 2,527,633 ac-ft were also high, 177 percent of the historical annual outflows (1,426,661 ac-ft) since 1972. During the wet season (June to October, 2014), surface water inflows into the lake was 2,292,910 ac-ft, higher than what the lake normally receives in a year. At the same time, 1,591,071 ac-ft was discharged from the lake to control the rise in stage. **Table 2-10** depicts WY2014, WY2013 and historical flow statistics for major impoundments. WY2014 monthly inflows and outflows are shown in Appendix 2-5, Tables 2 and 3, respectively. Monthly historical average, WY2013, and WY2014 inflows and outflows are shown in Appendix 2-6, Figures 3 and 4.

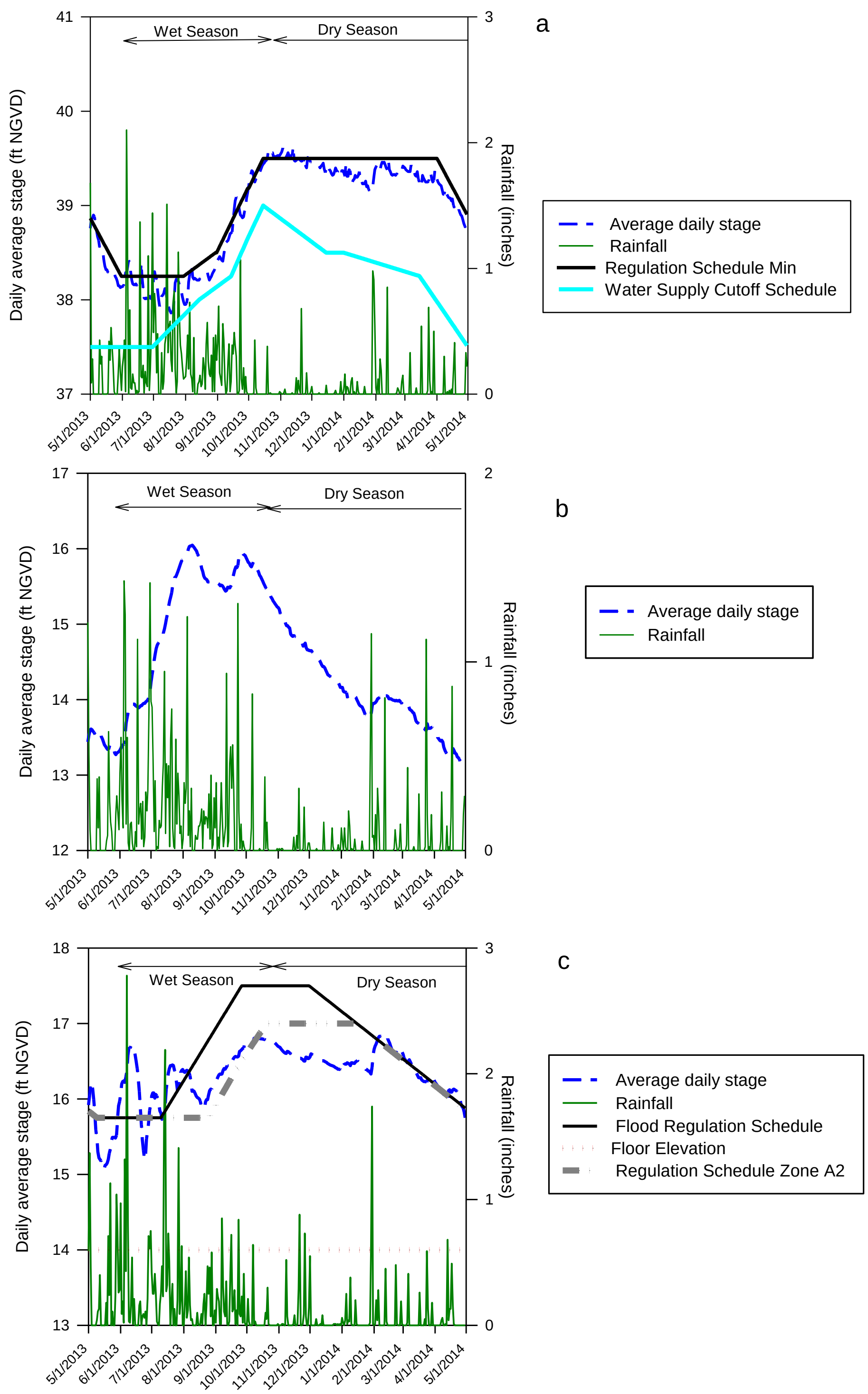


Figure 2-13. Average daily water levels (stage), regulation schedule, and rainfall for (a) Lake Istokpoga, (b) Lake Okeechobee, and (c) WCA-1.

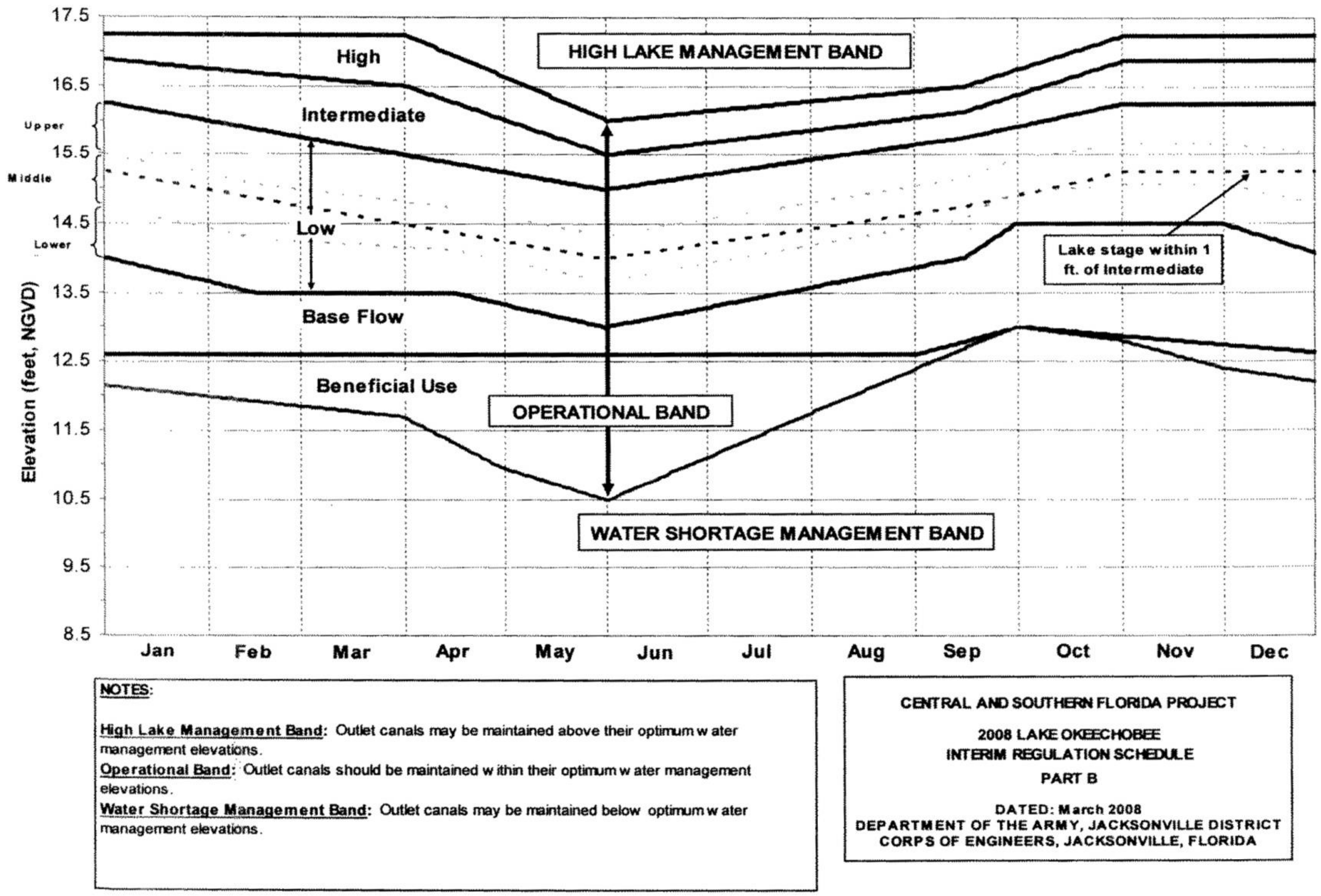


Figure 2-14. Lake Okeechobee's current regulation schedule (LORS2008).

As previously noted in the *Water Management in Water Year 2014* section of this chapter, the current regulation schedule for Lake Okeechobee is divided into three major bands: High Lake Management Band, Operational Band, and Water Shortage Management Band (**Figure 2-14**). The regulation schedule was developed by the USACE based on several key considerations including the lake's ecology and environmental needs, Caloosahatchee and St. Lucie estuaries' environmental needs, Everglades environmental needs, and structural integrity of the Herbert Hoover Dike and potential danger from hurricanes. While this regulation schedule attempts to balance the multipurpose needs of flood control, water supply, navigation, enhancement of fish and wildlife resources, and recreation, the dominant objective is public health and safety related to dike structural integrity. Notably, the 2008 regulation schedule has expanded operational flexibility throughout the year and allows Lake Okeechobee to be managed at lower levels than the previous regulation schedule. It is implemented through decision trees that consider lake water level, WCA water levels, tributary hydrologic conditions, multi-season climatic and hydrologic outlook, and downstream estuary conditions. The decision tree for establishing allowable lake releases to the WCAs and tide (estuaries) is shown in Abtew et al. (2011).

Upper East Coast and the St. Lucie Canal and Estuary

Inflows to the St. Lucie Canal are received from Lake Okeechobee by operation of S-308, a gated spillway, the Port Mayaca lock, and runoff from the basin (Abtew et al., 2011). The optimum water control elevations for the St. Lucie Canal vary between 14.0 and 14.5 ft NGVD. When the lake stage is below 14.5 ft NGVD and the S308 structure is open, runoff from the C-44 (St. Lucie Canal) basin flows back to the lake with the C-44 stage relatively higher. The outflow from the St. Lucie Canal that is not used in the basin for water supply or canal stage maintenance is discharged into the estuary via the S-80 structure. Runoff from the basin (C-44) is discharged to the estuary through S-80. WY2014 flows from Lake Okeechobee to the St. Lucie Canal were 444,651 ac-ft while inflow into the St. Lucie Estuary through S-80 was 675,722 ac-ft. Lake Okeechobee discharge through S-308 in to the St. Lucie Canal that is not used for water supply and is discharged to the estuary was estimated at 418,559 ac-ft. The estimated basin runoff discharged to the estuary was 257,154 ac-ft (**Table 2-10**). As salinity is an important measure of estuary viability, volume and timing of freshwater flow at S-80 is a key feature of water management activities.

The C-23 canal discharges into the North Fork of the St. Lucie River at structure S-48. The C-24 canal discharges into the same fork at S-49. The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50. Structure S-80 discharges water from the St. Lucie Canal into the South Fork of the St. Lucie River. Rainfall in Martin/St. Lucie rainfall area has increased from WY2013 by 5 inches. Outflows from the C-23 canal (S-48), C-25 canal (S-50) and the St. Lucie Canal (S-80) were higher than WY2013 (**Table 2-10**). WY2014 monthly flows for S-48, S-49, S-50, and S-80 are shown in Appendix 2-5, Table 4. Monthly historical average, WY2013, and WY2014 flows are shown in Appendix 2-6, Figures 5–8. Water management decision regulating releases through S-80 into the St. Lucie River is shown in **Figure 2-10**.

Lower West Coast

Inflows to the Caloosahatchee River (C-43 Canal) are runoff from the basin watershed and releases from Lake Okeechobee by operation of S-77, a gated spillway and lock structure (Abtew et al., 2011). Structure S-77 operations use regulation procedures described by the USACE (2008). Environmental water supply releases from the lake to the Caloosahatchee occurred at various times (**Figure 2-10**). WY2014 flows from Lake Okeechobee to the Caloosahatchee River were 1,225,613 ac-ft, which is 232 percent of the historical average. WY2014 monthly Lake Okeechobee flows through S-77 are shown in Appendix 2-5, Table 5.

Downstream of S-77, S-78 is a gated spillway that also receives runoff from the East Caloosahatchee Watershed, its local watershed. The optimum water control elevation for this portion of the Caloosahatchee Canal (upstream of S-78 and downstream of S-77) is between 10.6 and 11.5 ft NGVD. The outflow from the Caloosahatchee Canal (downstream of S-78) is discharged into the estuary via S-79, a gated spillway and lock operated by the USACE. The operations of S-79 include runoff from the West Caloosahatchee and Tidal Caloosahatchee watersheds. The optimum water control elevations near S-79 range between 2.8 and 3.2 ft NGVD. Because salinity is an important measure of estuary viability, the volume and timing of freshwater flow at S-79 is an important feature of water management activities. Water management decision regulating releases through S-79 into the Caloosahatchee Estuary is shown in **Figure 2-10**. The WY2014 discharge through S-79 to the coast, 2,521,600 ac-ft, was 204 percent of the historical average (1972–2014). The outflow from the Caloosahatchee Canal that is not used for water supply in the basins or canal stage maintenance is discharged into the estuary via the S-79 structure passing through S-78 along the route. Runoff from the basin (West Caloosahatchee and Tidal Caloosahatchee) is discharged to the estuary. Lake Okeechobee discharge through S-77 that passed through S-78, not used for water supply, but discharged to the estuary was estimated at 1,146,488 ac-ft. The estimated basin runoff discharged to the estuary was 1,377,052 ac-ft (**Table 2-10**). WY2014 monthly flows for S-77 and S-79 are shown in Appendix 2-5, Table 5; monthly historical average, WY2012, and WY2013 outflows at S-79 are shown in Appendix 2-6, Figure 9. **Table 2-10** depicts WY2014, WY2013 and historical flow statistics for major impoundments and canals.

Everglades Agricultural Area

Four major canals pass through the EAA: West Palm Beach, Hillsboro Canal, North New River Canal, and Miami Canal. Flows from Lake Okeechobee and runoff from the EAA are discharged via these four canals to relieve flooding for the local drainage area and into the Stormwater Treatment Areas (STAs) for water quality improvement. Discharges to the east coast occur through the West Palm Beach Canal. At times, when conditions do not allow for the STAs to treat all runoff water, diversion to the WCAs could occur. The inflows from Lake Okeechobee to these canals are from structures S-351, S-352, and S-354. These structures are gated spillways with a maximum tailwater elevation not to exceed 12 ft NGVD for Lake Okeechobee operation. The optimum water control elevations for S-351 and S-354 range between 11.5 and 12.0 ft NGVD. During WY2014, daily average elevations ranged from 9.50 to 12.13 ft NGVD. The outflows from the four canals to the STAs are discharged through pump structures S-5A, S-319, S-6, G-370, G-372, and G-434. Outflows from STAs are inflows into WCAs. During the dry season and drier-than-normal wet seasons, water supply for agricultural irrigation is provided by these four primary canals, mainly through gravity release from Lake Okeechobee. During droughts, when Lake Okeechobee levels are low, forward pumping is required to withdraw water from the lake. At times, water is also supplied to the EAA from the WCAs. Farmers utilize a set of secondary and tertiary farm canals to distribute water from several gated culverts and pumps to their respective fields.

Everglades Protection Area

Water Conservation Area 1

The primary objectives of the WCAs are to provide (1) flood control; (2) water supply for agricultural irrigation, municipalities, industry, and the ENP; (3) regional groundwater control and prevention of saltwater intrusion, (4) enhancement of fish and wildlife; and (5) recreation. A secondary objective is the maintenance of marsh vegetation in the WCAs, which is expected to provide a dampening effect on hurricane-induced wind tides (Abtew et al., 2011). WCA-1 covers approximately 141,440 acres with a daily average water level of 15.66 ft NGVD (1960–2014).

WCA-1 is regulated mainly by outflow structures S-10A, S-10C, S-10D, S-10E, and S-39; the regulation schedule for WCA-1 is provided by the USACE (1996). The main inflow structures G-251, G-310, and S-362 pump stations. Water supply releases are made through the G-94 (A, B, C), G-300, G-301, and S-39 structures. The regulation schedule varies from high stages in the late fall and winter to low stages at the beginning of the wet season (Abtew et al., 2007b). The seasonal range allows runoff storage during the wet season and water supply during the dry season. Water levels in WCA-1 started at 15.92 ft NGVD on May 1, 2013, and ended the year at 15.75 ft NGVD. Water level rose to a maximum of 16.83 ft NGVD in February 2014. The mean water year stage was 16.31 ft NGVD, 0.18 ft lower than WY2013 and 0.65 ft higher than the historical average. Four gauges (1-8C, 1-7, 1-8T, and 1-9) are used for stage monitoring. Daily water levels were compiled from the four gauges based on their regulation schedule uses. Site 1-8C was used from January 1–June 30, 2012, while the remaining sites (1-7, 1-8T, and 1-9) were used to calculate the average water level for the year, but only if the average was lower than that of site 1-8C. **Figure 2-13**, panel c, depicts WY2014 daily average water level, daily rainfall, and regulation schedule for WCA-1. Daily average historical water levels are shown in Appendix 2-3, Figure 10, for the period of record (1960–2014). Monthly historical average, WY2013, and WY2014 water levels are shown in Appendix 2-4, Figure 10. **Table 2-9** depicts WY2014, WY2013, and historical mean, maximum and minimum stages.

The main inflows into WCA-1 are from Stormwater Treatment Area 1 West (STA-1W) through the G-251 and G-310 pump stations and from Stormwater Treatment Area 1 East (STA-1E) via pump station S-362. There are three diversion structures that can flow in both directions (G-300, G-301, and G-338). The main outflow from WCA-1 is to WCA-2 through the S-10 structures. The two diversion structures (G-300 and G-301) are also used to discharge water from WCA-1 to the north to the L-8 and C-51 Canals via the STA-1 inflow basin. Water is also discharged through S-39 to the east into the Hillsboro Canal. The G-94A, B, and C structures are used to make water supply releases to the east urban area.

Historical flows through each structure have varying lengths of period of record because new structures come online, or because existing structures may no longer contribute to the inflow and outflow of a system. The structures related to the STAs are relatively recent additions. WCA-1 is regulated between 14 and 17.50 ft NGVD. WY2014 inflows into WCA-1 (380,269 ac-ft) were 80 percent of the historical average. In WY2014, 64 percent of the inflow was from STA-1W through pump stations G-310 and G-251, and 33 percent was from STA-1E through pump station S-362. No backflows occurred through the G-94s or S-10s. Minor inflow occurred through G-338. There was flood diversion inflow, 4 percent, through G-300 and G-301 during early June 2013 when excess rainfall occurred in central Palm Beach County from Tropical Storm Andrea and preceding wet conditions (**Figure 2-4**; **Tables 2-3**, **2-5**, and **2-6**; and Appendix 2-5, Table 6). Tropical Storm Andrea rainfall is presented in the *Water Year 2014 Hurricane Season* section, and its impact on the water management system to initiate diversion is documented in an after action report (SFWMD, 2013). Monthly historical average, WY2013, and WY2014 inflows are shown in Appendix 2-6, Figure 10.

WY2013 outflows from WCA-1 (471,206 ac-ft), were 107 percent of the historical average, for the analysis period from 1972–2014. Outflows from WCA-1 were mainly into WCA-2A through the S10 structures (70 percent) and to the east through S-39 and the Hillsboro Canal (26 percent); and some backflow through the G-300 structure for water supply into L-8 or C-51 Canal. Flow to the east through G-94A was 4 percent. **Table 2-10** depicts WY2014, WY2013, and historical flow statistics for major impoundments. WY2014 monthly outflows are shown in Appendix 2-5, Table 7. Monthly historical average, WY2013, and WY2014 outflows are shown in Appendix 2-6, Figures 11.

Water Conservation Area 2

WCA-2 is located south of WCA-1. An interior levee across the southern portion of the area subdivides it into WCA-2A and WCA-2B, reducing water losses due to seepage into the extremely pervious aquifer that underlies WCA-2B and precludes the need to raise existing levees to the grade necessary to provide protection against wind tides and wave run-up. Combined, WCA-2A and WCA-2B have a total area of 133,400 acres, with 80 percent of the area in WCA-2A. The regulation schedule for WCA-2A is provided by the USACE (1996). A regulation schedule is not used for WCA-2B because of high seepage rates. Releases to WCA-2B from S-144, S-145, and S-146 are terminated when the indicator stage gauge 99 in WCA-2B exceeds 11.0 ft NGVD. Discharges from WCA-2B are made from spillway structure S-141 to the North New River Canal when the pool elevation in WCA-2B exceeds 11.0 ft NGVD. For WY2014, the water level in WCA-2A started at 11.71 ft NGVD and reached a maximum of 14.43 ft NGVD in July 2013. Water level stayed above the regulation schedule throughout the water year. The average stage was 12.69 ft NGVD. Appendix 2-3, Figure 11 shows the daily water level for 1961–2014. **Figure 2-15**, panel a, depicts WY2014 daily average water level, daily rainfall, and regulation schedule for WCA-2A. **Table 2-9** depicts WY2014, WY2013, and historical mean, maximum and minimum stages. Monthly historical average, WY2013, and WY2014 water levels are shown in Appendix 2-4, Figure 11.

WY2014 inflows into WCA-2 (1,078,408 ac-ft) were 168 percent of the historical average and close to inflows in WY2013. The major inflows to WCA-2A were STA-2 discharges through pump station G-335 and G-436 (37 percent), STA-3/4 discharges through the S-7 pump station (32 percent), Outflow from WCA-1 through the S-10 structures (30 percent) and minor flows through S-142 and G-339.

WY2014 outflows from WCA-2 (965,358 ac-ft) were 150 percent of the historical average and close to outflows in WY2013. Outflows from WCA-2 were primarily into WCA-3A through structures S-11A, B, and C (71 percent) and discharge to canals 13 and 14 through structure S-38 (23 percent). This water year, there was no backflow into the EAA from WCA-2. There was outflow through the North New River Canal through structure S-34 (4 percent) and minor outflow through G-339. There was small discharge to WCA-3A through the S-142. WY2014 monthly inflows and outflows are shown in Appendix 2-5, Tables 8 and 9. Monthly historical average, WY2013, and WY2014 inflows and outflows are shown in Appendix 2-6, Figures 12 and 13, respectively. **Table 2-10** depicts WY2014, WY2013, and historical flow statistics for major impoundments and canals.

Water Conservation Area 3

WCA-3 is located south and southwest of WCA-2A. Two interior levees across the southeastern portion of the area subdivide it into WCA-3A and WCA-3B. These levees reduce water losses due to seepage into the extremely pervious aquifer that underlies WCA-3B. WCA-3A and WCA-3B combined have a total area of 585,560 acres, with 83 percent of the area in WCA-3A. The regulation schedule for WCA-3A is provided in USACE (1996). A regulation schedule is not used for WCA-3B because of high seepage rates. Indicator gauge 3B-2 is used for WCA-3B. Flow releases into WCA-3B are from the S-142 and S-151 structures, while releases from WCA-3B are through S-31 or S-337. Discharges from WCA-3B are rarely made from culvert L-29-1 for water supply purposes.

Figure 2-15, panel b, depicts WY2014 daily average water level, daily rainfall, and regulation schedule for WCA-3A. The previous regulation schedule, which was known as Interim Operational Plan for the Protection of the Cape Sable Seaside Sparrow, was replaced by a new regulation schedule known as Everglades Restoration Transition Plan (ERTP) as of October 19, 2012. Water levels in WCA-3 were above the flood regulation schedule during the wet months of June and July 2013 and below the flood regulation schedule in the 2014 dry season. The average stage was 10.23 ft NGVD with a maximum of 11.59 ft NGVD and minimum of 8.98 ft NGVD close to WY2013 levels. Appendix 2-3, Figure 12, shows the daily water level for 1962–2014. Monthly historical average, WY2013, and WY2014 water levels are shown in Appendix 2-4, Figure 12. **Table 2-9** depicts WY2014, WY2013, and historical mean, maximum, and minimum stages.

WY2014 inflows into WCA-3A (1,248,362 ac-ft) were 106 percent of historical average. The major inflows to WCA-3A in WY2014 were through S-11A, B, and C (55 percent) from WCA-2, and from STA-3/4 through structures S-8 (14 percent) and S-150 (2 percent). Inflows from the east through structures S-9 and S-9A accounted for 14 percent of the total inflow. The S-140 and S-190 structures to the northwest contributed 9 and 6 percent of the inflow to WCA-3A, respectively. There are possible inflows to WCA-3A through the L-4 borrow canal breach into the L-3 extension canal that is currently not gauged. The breach has a bottom width of 150 ft at an elevation of 3 ft NGVD (SFWMD, 2002).

WY2014 outflows from WCA-3A (1,452,583 ac-ft) were 144 percent of the historical average. Outflows from WCA-3A into the ENP were through structures S-12A, B, C, and D (53 percent); S-151 (12 percent); S-333 (18 percent) with potential flow to ENP to the south or flow east through S-334; S-344 and S-343 (9 percent); S-31 (7 percent) and S-30 (1 percent). There was minor flow through S-142, S-150 and S-337. There was minor backflow through S-8. WY2014 monthly inflows and outflows are shown in Appendix 2-5, Tables 10 and 11, respectively. Monthly historical average, WY2013, and WY2014 inflows and outflows are shown in Appendix 2-6, Figures 14 and 15. **Table 2-10** depicts WY2014, WY2013, and historical flow statistics for major impoundments and canals.

Everglades National Park

Everglades National Park is located south of WCA-3A and WCA-3B. Criterion for water delivery into the Park was the new ERTP regulation replacing the Interim Operational Plan as of October 19, 2012. Water level monitoring at sites P-33 and P-34 has been used in previous reports as representative of slough and wet prairie, respectively (Sklar et al., 2003). Station elevations for P-33 and P-34 are 5.06 and 2.09 ft NGVD, respectively (Sklar et al., 2000). Historical water level data for sites P-33 (1952–2014) and P-34 (1953–2014) were obtained from the District's hydrometeorology database, DBHYDRO, and from ENP's database. Water level at both sites was higher than WY2013 and the historical average. The WY2014 average water level at P-33 was 6.63 ft NGVD and at P-34 was 3.24 ft NGVD. **Figure 2-15,** panels c and d, depict the daily average water level and rainfall at P-33 and P-34, respectively, for WY2014. Daily average historical water levels for P-33 and P-34 are shown in Appendix 2-3, Figures 13 and 14, respectively. Monthly historical average, WY2013, and WY2014 water levels for P-33 and P-34 are shown in Appendix 2-4, Figures 13 and 14, respectively. **Table 2-9** depicts WY2014, WY2013, and historical mean, maximum, and minimum stages.

WY2014 inflow into the ENP (1,590,971ac-ft) was 161 percent of the historical average and higher than WY2013. Inflow into the ENP is mainly through structures S-12A, B, C, D, and E; S-18C, S-332B, S-332C, S-332D, S-333, S-199, and S-200. The major inflow (49 percent) was through the S-12 structures. The S-332B structure contributed (11 percent); S-332C (11 percent); S-332D (8 percent); S-18C (8 percent); S-333 (7 percent); S-200 (4 percent); and S-199 (2 percent). S-175 had relatively small flows. WY2014 monthly inflows are shown in Appendix 2-5, Table 12. Monthly historical average, WY2013, and WY2014 inflows are shown in Appendix 2-6, Figure 16. **Table 2-10** depicts WY2014, WY2013, and historical flow statistics for major impoundments.

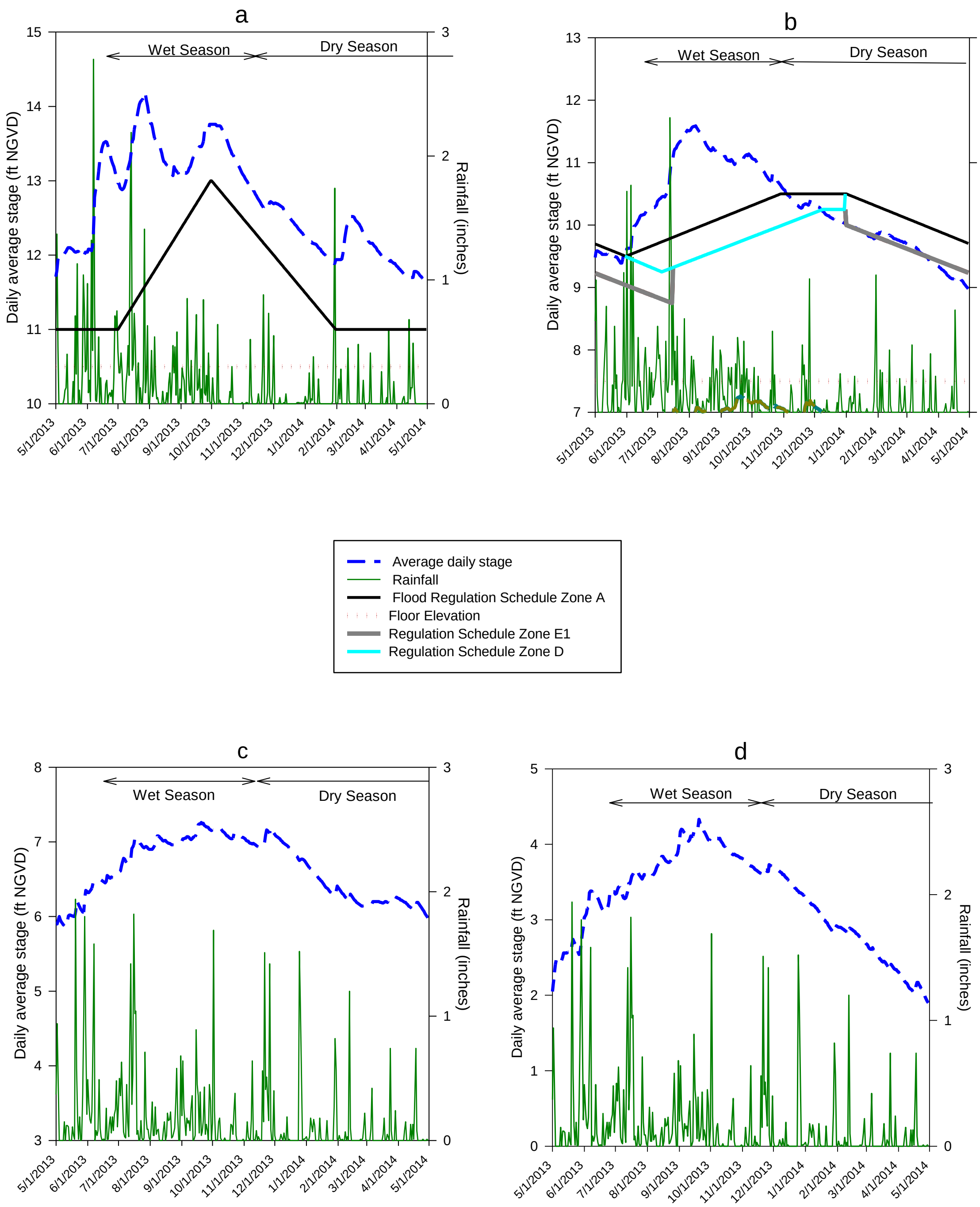


Figure 2-15. Average daily water levels (stage), regulation schedule, temporary deviation, and rainfall for (a) WCA-2A, (b) WCA-3A, (c) gauge P-33, and (d) ENP (gauge P-34).

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